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THE HISTORY OF MITRAL STENOSIS

BY

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The early observations on mitral stenosis were largely made in France and Britain, and in the past its clinical diagnosis was probably more discussed than that of any other form of valvular disease of the heart.

As the study of morbid anatomy is much older than the practice of auscultation, the lesion of mitral stenosis was described more than a hundred and fifty years before its clinical recognition received the help of auscultation. Extreme constriction of the mitral orifice in a young man was recorded in 1668 by John Mayow (1640–1679), an Oxford physiologist contemporary with Richard Lower (1631–1691), whose *Tractatus de corde* appeared in 1669. The morbid change in a case was more fully reported in 1715 by another contemporary, Raymond de Vieussens (1641–1715) of Montpellier, with an illustration of the mitral valve, reproduced in Major's *Classic Descriptions of Disease*. Morgagni (1682–1771) also recorded the lesion in 1761, under the title " ossification of the mitral valve."

Physical Signs

In 1806 J. N. Corvisart (1755–1821), called by Andral " the Morgagni of France," and in 1819 his pupil R. H. T. Laennec (1781–1826) began the description of the physical signs of mitral obstruction which, following Morgagni, they designated as ossification or calcification of the mitral valve. Corvisart gave an account of the rustling or thrill palpable over the heart as characteristic of the lesion and ascribed it to obstruction to the passage of the blood from the lungs and left auricle through the narrowed mitral orifice.

> Number cliv of his aphorisms, collected by his pupil Mérat (1780–1851), but not published until 1929, is to the effect that on placing the hand over the præcordia a thrill is felt, which resembles that experienced by the hand while stroking a cat. The aphorisms were translated into English in 1939 by McDonald.

Laennec is sometimes referred to as the original describer of this sign ; probably because in 1819 he employed the term *frémissement cataire ;* he, however, stated that Corvisart was the first to make this observation.

Allan Burns (1781–1813), anatomical and surgical lecturer in Glasgow, in 1809, in a report of one of three cases of mitral stenosis confirmed at necropsy, wrote : " there was a jarring when the ventricles contracted ; and when the hand was laid on the side, it resembled the feel of a varicose aneurism . . . he

had unusual palpitation, jarring sensation, and a hissing noise, as of several currents meeting ; the sound was often audible as in varicose aneurism." These signs were, however, ascribed to mitral regurgitation, and he went on " in all probability, it is something of this kind which is described as audible palpitation in some diseases of the heart." It thus appears that he recognized the thrill and also seems to have realized the mechanism (fluid vein) of a cardiac murmur. No reference is made to Corvisart's description of the thrill, and on account of the Napoleonic wars it is probable that he had not any opportunity of seeing Corvisart's essay. Robert Adams (1791–1875), Regius Professor of Surgery in the University of Dublin and author of an outstanding work on chronic arthritis (1857), recognized, apparently independently, this thrill in 1827.

The auscultatory signs of mitral stenosis have been a somewhat confusing battlefield of opinion. Corvisart in his aphorisms did not mention a murmur. Laennec and his followers, who attached more importance to obstruction than to incompetence of the valves in the causation of murmurs, believed that the passage of blood through a narrowed mitral orifice produced a direct, not a regurgitant, murmur, either a soft bellows (*bruit de soufflet*) or less often a rough rasping (*bruit de scie ou de râpe*) murmur. What Laennec did not do was to fix the exact point in the cardiac cycle at which this took place.

> In February 1819 he examined a boy, aged 16 years, with a thrill and accompanying murmur, both ascribed to the prolonged contraction of the left auricle, the murmur being " dull but strong, exactly like that produced by the stroke of a file on wood."

Andral (1797–1876) in his annotated edition (1837) of Laennec's *Traité de l'auscultation médiate* drew a practical distinction in the significance of the *bruit de râpe*, which was evidence of organic obstruction, and of the bellows murmur. In a note on the history of valvular diseases of the heart Sir Samuel Wilks (1824–1911) in 1871 pointed out how remarkable it was that this simple view, closely resembling that of more recent times, should so soon have been abandoned in favour of its regurgitant nature ; he suggested that this may have been because Laennec and others erroneously considered that the second sound of the heart was due to the auricular systole, and that when the true nature of the second sound was discovered, physicians, instead of " simply correcting the fault, swept away the whole idea of this direct mitral murmur. At least, this is what, for the most part, occurred, and the teaching of the schools was that all mitral and apex bruits were of a regurgitant nature. . . . It is a recent revival to speak of direct mitral bruits." Laennec had attributed the first sound of the heart to the ventricular systole and the second sound to the auricular systole. That the second sound was due to the closure of the sigmoid valves and not to the contraction of the auricles was shown by J. W. Turner (1790–1836) of Edinburgh in 1829, and by the experimental work between 1830 and 1836 of James Hope (1801–1841) and C. J. Blasius Williams (1805–1889), who owed this unusual christian name to his birth on February 3, the day on which St. Blaise or Blasius underwent martyrdom in A.D. 316.

Though a relatively small matter of priority, it hardly seems reasonable that

R. J. Bertin (1767–1827), who held the same views as Laennec about the production of the heart sounds, should sometimes be picked out, rather than Laennec, to have been the first to listen to what was in reality a presystolic murmur.

Bertin reported six cases in which mitral obstruction was found at necropsy ; in three of them, early in the century before Laennec invented auscultation, no mention of a murmur was made ; in the other three a bellows murmur was recorded, which later in his book was said to be pathognomonic. Very likely he may have heard a presystolic murmur, but he did not describe it as rasping or presystolic.

In 1832 Hope described the second sound of the heart on the left side of the sternum in mitral stenosis as altered, i.e. losing its short, flat, clear character and becoming a more or less prolonged bellows murmur. " When the valve is permanently patescent, admitting of regurgitation, the first sound likewise is attended with a murmur." The first above-mentioned murmur was formerly known as Hope's early diastolic murmur. In the third edition (1839) of his *Treatise* Hope mentioned that he had carefully listened for a murmur due to the auricular systole, but without success. Subsequently this diastolic murmur was ascribed to dilatation of the trunk of the pulmonary artery so that its valve segments became relatively incompetent, and has been called the murmur of high blood pressure in the pulmonary artery (Graham Steell, 1888). Williams, the early colleague as an experimental cardiologist of Hope and later his rather unfriendly rival, stated in 1840 that this diastolic murmur in mitral obstruction was very rare, as he had recognized it in two or three cases only. He referred to its possible production by the suction-pump action of negative pressure due to the diastolic expansion of a well-developed left ventricle.

Fauvel and the Presystolic Murmur

The view that the murmur characteristic of mitral stenosis was due to regurgitation of blood from the ventricle into the auricle was until after 1861 (see p. 5) commonly but not universally held, and was indeed revived more than once after that date (see p. 7). In 1843, however, Fauvel (1813–1884), chief of the clinic of the Paris Faculty of Medicine at the Hôtel-Dieu, Paris, described, with five illustrative cases (three with necropsy) of mitral stenosis, the presystolic murmur.

He was careful to acknowledge that the word " presystolic " was taken from Gendrin (1796–1890), who in 1841 had divided the cycle of the heart into six periods : systole, perisystole (immediately following), presystole (immediately preceding systole) ; diastole, peridiastole, and prediastole (p. 32). Gendrin laid it down that obstruction to the passage of blood from the auricle to the ventricle caused a prediastolic murmur, adding that the systolic, perisystolic, and prediastolic murmurs were often continuous (p. 110). He regarded reduplication of the second sound as evidence of mitral stenosis.

Fauvel shared the fate of the prophet in his own country : Bouillaud (1796–1881) did not support his junior, being probably more interested in a triple bruit (*de rappel*) at the base of the heart, which he described in 1836. In 1853

Hérard (1819–1913) stated that mitral stenosis might be associated, in varying degrees of frequency, with a systolic, presystolic, or diastolic murmur. In 1862 Duroziez (1826–1897) referred to "that famous presystolic murmur of which everyone talks but no one understands." In Germany Canstatt (1807–1850), of Ratisbon, in 1848 confirmed Fauvel's views, and aroused criticism from Wintrich (1812–1882), who in 1849 concluded that it was a rather interesting *article de luxe* of physical diagnosis (Hilton Fagge). In Great Britain Fauvel's article attracted hardly any attention, though destined eventually

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(1838–83)
By the courtesy of the late C. H. Fagge, M.S., F.R.C.S., and of the Oxford University Press.

to become a milestone in the history of the disease. Thomas Addison (1793–1860) "never distinguished a presystolic bruit from a systolic one, and openly taught that he was quite unable to diagnose a contracted auriculo-ventricular orifice from a dilated one" (Wilks). William Stokes (1804–1878), Regius Professor of Physic in Dublin, did not welcome the new murmur ; in 1854 he wrote :

> "To the inexperienced, the detailed descriptions of such phenomena as the intensification of the sounds of the pulmonary valves, of constrictive murmurs as distinguished from non-constrictive, of association of different murmurs at the opposite sides of the heart, of pre-systolic and post-systolic, pre-diastolic and post-diastolic murmurs, act injuriously : . . . by conveying the idea that the separate existence of these phenomena is certain, and that their diagnostic value is certain."

In 1871 Hilton Fagge (1838–1883), realizing the importance of Fauvel's description of the presystolic murmur and finding that it had not been noticed in detail by British writers, gave a full abstract of it. He pointed out that it would not be strictly accurate to assume that British physicians entirely overlooked the direct mitral murmur and its presystolic character until Gairdner's paper in 1861. Several, such as Peter Mere Latham (1789–1875) in 1845, Bellingham (1805–1857), a Dublin surgeon, in 1853, and Markham (1818–1891) in 1854 and 1860, described it as simply diastolic. Some said it was very rare ; thus in 1851 Herbert Davies (1818–1885) had never heard it, and in the same year Ormerod (1819–1873) stated that a direct mitral murmur was one of the rarest morbid cardiac sounds and that he had identified it in two cases only.

W. H. Walshe (1812–1892), born in Dublin and endowed with the brilliancy of a clever Irishman, educated medically chiefly in Paris, M.D. of Edinburgh, and physician to University College Hospital in London, appears to have been in 1851 the first in Great Britain to recognize the presystolic character of the direct mitral murmur in mitral stenosis ; he spoke of the diastolic murmur as rather post-diastolic or presystolic than as coinciding precisely with the ventricular diastole.

In 1859 Austin Flint, the elder (1812–1886), then of New Orleans and later of the Bellevue hospital, New York, stated that a direct diastolic mitral murmur " follows the second or diastolic sound of the heart and precedes the systolic or first sound." He regarded this diastolic mitral murmur as rare because the contractions of the auricle were not sufficiently powerful, but did not refer to Fauvel or actually use the adjective " presystolic " then.

Gairdner and the Auricular-systolic Murmur

In 1861 Sir William Gairdner (1824–1907), then of Edinburgh and from 1862 to 1890 Regius Professor of the Practice of Medicine in the University of Glasgow, described under the title " auricular-systolic " (A.S.) the murmur Fauvel had called presystolic. Gairdner's " Short Account of Cardiac Murmurs," which did not refer to Fauvel, " marked " according to G. A. Gibson (1854–1912) of Edinburgh, Gairdner's biographer, the " commencement of a new epoch in physical diagnosis." It was largely responsible for the eventual recognition of the presystolic murmur in Great Britain. Gairdner also described a direct mitral murmur, ventricular-diastolic in time and coincident with the filling of the ventricle by its rapid expansive action. In the second edition (1867) of his *Treatise*, Austin Flint preferred " auricular-systolic " to presystolic as the qualifying adjective.

After Gairdner's important paper, opinion still fluctuated before its acceptance became general. The history and position in 1871 were exhaustively reviewed by Hilton Fagge, whose paper also contained many clinical observations, especially about the rhythm of murmurs and the state of the sounds of the heart, on 67 cases in Guy's Hospital. In 1865 James Andrew (1829–1897), of St. Bartholomew's Hospital, and in 1867 T. B. Peacock (1812–1882), of St. Thomas's Hospital and a prominent authority on cardiac disease, especially on

congenital malformations, spoke of the recognition of a presystolic murmur as " one of the most difficult tasks in the physical examination of the heart, and often all but impossible, at least in the later periods of the disease." This disappearance of the murmur had to wait for an explanation until the discovery of auricular fibrillation early in this century by Sir James Mackenzie (1853–1925), who first called it " nodal rhythm " and thought it due to paralysis of the

Sir William Tennant Gairdner, K.C.B., M.D., F.R.S.
(1824–1907)

From a photograph taken during the later years of his life in Glasgow by Messrs. T. & R. Annan & Sons.

left auricle, and of the electrocardiographic and other observations of Sir Thomas Lewis. Physiologists had experimentally produced fibrillation of the heart muscle in the last century (Gaskell ; MacWilliam). Hyde Salter (1823–1871), physician to Charing Cross Hospital, in a clinical lecture published in 1869 declared that the presystolic was the easiest of all cardiac murmurs to detect and that for 30 years physicians had regarded it as systolic in time.

Hilton Fagge agreed with the last statement, but gently added " it is perhaps going a little too far " (as Salter did), " even in addressing a class of students, to say that now anyone who should fail to recognize and identify this sound would not only be unfit to hold the place of an accomplished and critical physician but could hardly be considered as a decently informed member of our profession."

The Austin Flint Murmur

Presystolic murmurs have been ascribed to causes other than ordinary organic mitral stenosis. The best established is the Austin Flint murmur at the apex beat in aortic regurgitation. Austin Flint, in describing it in 1862, explained its mechanism as follows : " in aortic incompetence the left ventricle is rapidly filled with blood regurgitated from the aorta in addition to that from the left auricle, as a result the mitral curtains are brought into coaptation, and when the auricular contraction takes place this direct mitral current passing between the curtains throws them into vibration and gives rise to the characteristic blubbering murmur. The physical condition is in effect analogous to contraction of the mitral orifice from an adhesion of the curtains at their sides." Austin Flint thus specially incriminated vibration of the valve segments, but his mention of " coaptation " does not entirely exclude the later view, namely that impingement of the regurgitant blood from the aorta on the anterior cusp of the mitral valve bulges that flap in so as to narrow the mitral orifice (Guitéras)—an inorganic stenosis ; evidence of this has been adduced in the presence of endocardial thickening of the auricular surface of the mitral valve. Flint's accuracy in timing the presystolic murmur in aortic reflux uncomplicated by mitral stenosis was bluntly questioned by G. W. Balfour (1823–1903), who in 1876 warned his Edinburgh students not to make such a mistake. Flint naturally protested against this in 1884 and 1886. In his thesis for the M.D. degree at Cambridge in 1895 A. G. Phear analysed 46 cases in which the murmur was present without mitral stenosis, but associated with aortic incompetence or some other cardiac lesion. In 1901 W. S. Thayer (1864–1932) found that Flint's murmur was present in 63 per cent. of cases of aortic incompetence proved by necropsy to be free from mitral stenosis. This presystolic murmur in association with aortic reflux is now fully accepted. A presystolic murmur has also been described in cardiac conditions other than aortic incompetence or mitral stenosis : in 20 of Phear's 46 cases there was an adherent pericardium, and in some others with dilatation of the left ventricle. When a presystolic murmur has been heard in a case in which great dilatation of the left side of the heart is the chief lesion found, it has been suggested that it is due to relative or virtual stenosis, though without any absolute constriction of the mitral orifice (Rolleston and Dickinson, 1897). Another view is that the murmur may be due to the meeting of two columns of blood, one direct from the auricle, the other regurgitant from the ventricle into the auricle (Allan Burns).

Systolic, Presystolic, or Diastolic

Not long after the presystolic murmur was gaining acceptance in Britain criticism arose not about its diagnostic significance, but to the effect that it was really systolic in time. This was argued in 1864 by Ormerod, followed in 1868 by Leaming (1820–1892) of New York, Barclay (1817–1884) of St. George's Hospital, London, in 1872, F. Donaldson (1823–1891) of Baltimore in 1874, who, like Leaming, was said to have an accomplished ear for musical and other sounds, by Sir D. C. McVail (1845–1917) of Glasgow in 1879, quite briefly, by Dickinson (1832–1913), physician to St. George's Hospital, in 1887 and 1889, who wrote at length and rather provocatively on " the presystolic murmur falsely so called," by F. C. Turner (1843–1900) of the London Hospital, in 1887, and by E. M. Brockbank in six papers between 1897 and 1910, who used the phrase " the crescendo murmur of mitral stenosis." In 1911 Hart concluded that " in some cases at least the short crescendo murmur preceding the first sound in mitral stenosis is not due to auricular activity." At irregular intervals there were thus revivals of the old view about the nature of the murmur, which aroused much criticism, for example from G. W. Balfour in 1872, T. D. Acland (1851–1931) in 1889, and from Sir F. Taylor (1847–1920) and Sir John Broadbent in 1909, and Sir T. Lewis in 1911. These battles long ago are now as if they had never been.

In 1866 Hayden (1823–1881) of Dublin recorded six cases with a presystolic murmur, three confirmed as regards mitral stenosis by necropsy, and stated that in mitral stenosis embarrassment of respiration and œdema are much less prominent than in mitral incompetence, and that the presystolic murmur is not transmitted to the left side of the lower dorsal spine. He also spoke of post-diastolic and post-ventricular murmurs. From cardiographic records Galabin (1843–1913) in 1875 concluded that two totally distinct murmurs may be caused by mitral obstruction : (1) the auricular-systolic and (2) a diastolic, due to the venous flow through the narrowed and roughened mitral orifice, which may be separated from the auricular-systolic murmur. James Andrew in 1877, while deprecating complicated expressions such as auricular-systolic and post-diastolic, admitted that as all direct mitral murmurs are diastolic, it was advisable to describe them in three groups according to the position of the murmurs in diastole. J. S. Bristowe (1827–1895) of St. Thomas's Hospital in 1887 followed this up by describing as the murmurs of mitral stenosis the three murmurs : (i) the early diastolic, taking the place of the second sound, thus resembling the diastolic murmur of aortic incompetence, audible on the left side of the sternum—this was later explained by pulmonary regurgitation caused by dilatation of that artery from increased venous pressure (see p. 3); (ii) the mid diastolic murmur, which may imitate a reduplicated sound, and has been ascribed to the suction action of the expanding left ventricle, a *vis a fronte*, as suggested by C. J. B. Williams (see p. 3) ; and (iii) the late diastolic or presystolic murmur.

Sir W. H. Broadbent (1835–1907) in 1886 described three stages of mitral stenosis : (*a*) with good compensation and a presystolic murmur and second sound audible at the apex ; (*b*) the period of strained compensation in which the

second sound is absent at the apex and the first sound becomes short, usually very loud, and so may be erroneously regarded as the second sound and the presystolic murmur running up to it as systolic in time ; (c) in the third stage, in which the compensation has completely broken down, the presystolic murmur has disappeared, probably as the result of tricuspid incompetence. It was more than twenty years later that the important factor of auricular fibrillation was established by Mackenzie and Lewis (see p. 6). Broadbent discussed the variations in the pulse from a regular rhythm in the early stage to extreme irregularity later, as Stokes had done, and described a moderately high blood pressure. He also commented on the frequency with which œdema was absent, and associated the presence of extreme œdema with the complication of tricuspid stenosis.

Associated Conditions

Tricuspid stenosis, when present, is nearly always associated with mitral stenosis which is in a more advanced stage. Isolated cases in this bilateral auriculo-ventricular stenosis were recorded by Morgagni (1761), Crüwell (1765), Corvisart (1806), Horn (1808), Allan Burns (1809), Laennec (1823), and Bertin (1824). Bedford Fenwick (1882) collected 70 such cases ; Leudet (1888) found among 114 collected cases of tricuspid stenosis 103 with mitral stenosis, and Newton Pitt (1853–1929) among 109 cases of tricuspid stenosis from the records of Guy's Hospital found that all but two showed mitral stenosis.

A ball thrombus in the left auricle in mitral stenosis was reported in 1814 by Wood in Edinburgh. Allan Burns in 1809 described an early stage of a loose ball-clot in mitral stenosis: " the left auricle contained a concretion larger than a pigeon's egg, firmly adherent to the skin of the cavity, and composed of several portions forcibly pressed together," and Robert Adams recorded a case in 1827. In 1909 Welch collected 19 cases associated with mitral stenosis, and it has been suggested that impaction of the ball-thrombus in the stenosed mitral may cause sudden death, but Welch's analysis gave little support to this possibility. Cases of intra-auricular ball-thrombi and tumours without mitral stenosis may imitate ordinary mitral stenosis (Thompson and Aitchison).

Pulmonary apoplexies, described in 1819 by Laennec, appear to have been first correlated with mitral obstruction by J. A. Wilson (1795–1882), physician to St. George's Hospital from 1829 to 1857, in a paper read before the Royal College of Physicians of London on the evening of March 22, 1830, but only reported briefly in the *London Medical Gazette*, in which three cases seen in a short period of six weeks were reported. This was confirmed in 1832 by Hope and about the same time by Sir Thomas Watson (1792–1882). In 1896 W. L. Dickinson (1862–1904) published in full his grandfather's three cases, but on analysis of 70 necropsies showing the presence of pulmonary apoplexies was surprised to find that sixteen only were associated with mitral stenosis, most of the others undoubtedly showing mitral regurgitation. T. B. Peacock in 1867 argued that, as the pulmonary vessels underwent gradual dilatation, pulmonary apoplexies were not prone to occur ; whereas Hyde Salter stated in 1869 that

hæmoptysis is more likely to occur in mitral obstruction than in other forms of cardiac disease.

Pressure exerted by a greatly dilated left auricle on the left bronchus and collapse of much of the left lung was recorded in 1889 by T. D. Acland, who referred to two such specimens in the Guy's Hospital museum.

I am much indebted to Dr. Maurice Campbell for the following note. " In 1838, T. Wilkinson King (1809–1847), curator of the Museum and lecturer on morbid anatomy at Guy's Hospital, published a paper ' On a Morbid Flattening or Compression of the Left Bronchus produced by dilatation of the left auricle.' He summarized his conclusions as follows :—

> " ' A particular morbid effect, which, as far as I am informed, has not been made known, and which, as I believe, is of rather common occurrence, is the flattening and obstruction of the left bronchus, when the left auricle is dilated so as to press upon this air-tube. Our Collection affords three specimens of this affection; and I think I may say I have remarked it many times, in different degrees. I propose to make a brief reference to the most remarkable instances of those which I have recorded; as well as to a few concurrent circumstances, which may explain what is necessary to the production of this compression, as well as what should be looked for in connexion with it.
>
> " ' I have been able correctly to anticipate the existence of this change, by considering the state of the heart ; but I have hitherto perceived nothing distinctive in the respiratory sounds, and, indeed, should not expect to do so.'

The cases, specimens of which are still in the Guy's Museum and show the compression of the left bronchus very clearly, were (1) a boy of 15 with rheumatic heart disease and mitral stenosis, who died with congestive failure with pleural and pericardial effusions, (2) a man of 28 with mitral stenosis and an adherent pericardium, and (3) a woman of 21 with mitral stenosis and a slighter degree of tricuspid stenosis, who died with general congestive failure. In the first two cases the great dilatation of the left auricle was emphasized; in the third case there was much dilatation of both auricles, especially the left. A fourth case was mentioned in which the left bronchus was compressed, probably from a dilated right auricle associated with a patent foramen ovale."

Paralysis of the left recurrent laryngeal nerve, causing cough and aphonia, and associated with mitral stenosis, was described in two patients in 1897 by Ortner (1865–). In 1920 Garland and White collected 61 cases of dilatation of the left auricle, and agreed with Fetterolf and Norris that such dilatation alone did not explain the compression of the nerve and that the left pulmonary artery played a part in the process. Enormous dilatation of the left auricle may occur without mitral stenosis (see Ewart and Owen).

References

Acland, T. D. (1889). *Lancet*, **2**, 103, 149.
Adams, R. (1827). *Dublin Hosp. Rep.*, **4**, 434.
Andrew, J. (1865). *St. Bartholomew's Hosp. Rep.*, **1**, 13.
—— (1877). *Ibid.*, **13**, 1.
Balfour, G. W. (1872). *Lancet*, **1**, 714.
—— (1876). *Clinical Lectures on Diseases of the Heart and Aorta*, Lond.
Barclay, A. W. (1872). *Lancet*, **1**, 283.
Bertin, R. J. (1824). *Traité des maladies du coeur*, Paris, pp. 171–198 ; 225.

Bouillaud, J. B. (1836). *Traité cliniques de maladies du coeur*, Paris.
Bristowe, J. S. (1887). *Lancet*, **2**, 952.
Broadbent, W. (1886). *Amer. J. med. Sci.*, **91**, 57.
Brockbank, E. M. (1897). *Med. Chron.*, **7**, 161.
—— (1910). *Quart. J. Med.*, **3**, 345.
Burns, A. (1809). *Observations on some of the most frequent and important Diseases of the Heart*, pp. 174–189. Edinb.
Canstatt, K. F. (1848). Quoted by Fagge.
Corvisart, J. N. (1806). *Essai sur les maladies et les lésions organique du coeur*, p. 236. Paris.
Crüwell, H. A. (1765). *De cord. et vas. osteogen.* Halle.
Davies, H. (1851). *Lectures on the Physical Signs of Diseases of the Lungs and Heart.* Lond. p. 271.
Dickinson, W. H. (1887). *Lancet*, **2**, 650 ; 695.
—— (1889). *Ibid.*, **2**, 779.
Dickinson, W. L. (1896). *St. George's Hosp. Gaz.*, **4**, 181.
Duroziez, P. L. (1862). *Arch. gén. de méd.*, sér. V, **20**, 390.
Ewart, W., and Owen, I. (1902). *Trans. Clin. Soc. Lond.*, **35**, 142 ; 147.
Fagge, C. H. (1871). *Guy's Hosp. Rep.*, 3rd ser., **16**, 247–342 (History).
Fauvel, S. A. (1843). *Arch. gén. de méd.*, Paris. sér. 4, **1**, 1.
Fenwick, B. (1882). *Trans. path. Soc. Lond.*, 33, 64.
Fetterolf, G., and Norris, G. W. (1911). *Amer. J. med. Sci.*, **141**, 625.
Flaxman, N. (1938). *Med. Life*, **45**, 3 (History).
Flint, A. (1859). *Practical Treatise on the Diagnosis, Pathology and Treatment of Diseases of the Heart.* Phila., and second edition, 1867.
—— (1862). *Amer. J. med. Sci.*, **44**, 29.
—— (1884). *Lancet*, **1**, 418.
—— (1886). *Amer. J. med. Sci.*, **91**, 38.
Gairdner, W. T. (1861–2). *Edinb. med. J.*, **7**, 445.
Galabin, A. L. (1875). *Guy's Hosp. Rep.*, 3rd ser., **20**, 261.
Garland, J., and White, P. D. (1920). *Arch. intern. med.*, **26**, 343.
Gaskell, W. H. (1900). *Textbook of Physiology* (A. E. Schäfer), Edinb., vol. 2, p. 16.
Gendrin, A. N. (1841). *Leçons sur les maladies du coeur*, Paris, pp. 32, 110.
Gibson, G. A. (1912). *Life of Sir W. T. Gairdner*, Glasgow, p. 682.
Guitéras, J. (1887). *Trans. Ass. Amer. Phys.*, **2**, 37.
Hart, T. S. (1911). *Med. Rec.*, **80**, 2.
Hayden, T. (1866). *Med. Pr.*, I, 680 ; II, 5, 32.
Hérard, H. (1853). *Arch. gén. de méd.*, Paris, sér. 5, **2**, 543.
Hope, J. (1832). *Treatise on Diseases of the Heart and Great Vessels.* Lond. p. 341.
—— (1839). *Ibid.*, 3rd edit., p. 78.
King, T. W. (1838). *Guy's Hosp. Rep.*, 3rd ser., 175.
Laennec, R. T. H. (1819). *Traité de auscultation médiate et des maladies des poumons et de coeur*, Paris, t. 2, p. 321.
—— (1837). *Ibid.*, edited by Andral, t. 3, p. 107.
Latham, P. M. (1845). *Lectures on Subjects connected with Clinical Medicine comprising Diseases of the Heart.* Lond.
Leaming, J. R. (1868). *Cardiac Murmurs.* New York.
Lewis, T. (1911). *Quart. J. Med.*, **4**, 301.
McDonald, A. L. (1939). *Ann. med. Hist., New York*, 3rd ser., I, 553.
McVail, D. C. (1879). *Glasg. Med. J.*, **11**, 337.
Major, R. H. (1932). *Classic Descriptions of Disease*, Springfield, p. 336 *et seq.*
Mayow, J. (1668). *Tractatus de respiratione.* Oxon. p..38.
Morgagni, G. B. (1761). *De sedibus et causis morborum.*
Ormerod, E. L. (1851). *Lond. med. Gaz.*, **47**, 533.
—— (1864). *Med. Times and Gaz.*, **2**, 154.
Ortner, N. (1897). *Wien. klin. Wschr.*, **10**, 753.
Peacock, T. B. (1867). *Brit. and For. med.-chir. Rev.*, **40**, 489.
Phear, A. G. (1895). *Lancet*, **2**, 716.
Pitt, G. N. (1909). *System of Medicine* (Allbutt and Rolleston), Lond., 6, 330.
Rolleston, H. D., and Dickinson, W. L. (1897). *Lancet*, **1**, 659.
Salter, H. (1869). *Ibid.*, **2**, 565, 601.
Steell, G. (1888). *Med. Chron.*, **9**, 182.
Stokes, W. (1854). *Diseases of the Heart and Aorta.* Dublin, p. 181.
Thayer, W. S. (1901). *Trans. Ass. Amer. Phys.*, **16**, 393.
Thompson, H. T., and Aitchison, C. V. (1904). *Trans. Clin. Soc. Lond.*, 37, 192. (Bibliography.)
Turner, F. C. (1887). *Lancet*, **2**, 933.
Turner, J. W. (1829). *Trans. med.-chir. Soc.*, Edinb., 3, 226.
Vieussens, R. (1715). *Traité nouveau de la structure et des causes du mouvement naturel du coeur*, Toulouse, p. 101.

Walshe, W. H. (1851). *Practical Treatise on Diseases of the Lungs and Heart*, Lond., p. 226.
Welch, W. H. (1909). *System of Medicine* (Allbutt and Rolleston), Lond., **6**, 721.
Wilks, S. (1871). *Guy's Hosp. Rep.*, 3rd ser., **16**, 212.
Williams, C. J. B. (1836). *Rep. Brit. Ass. Adv. Sci.*
—— (1840). *The Pathology and Diagnosis of Diseases of the Chest*, Lond., p. 273.
Wood, W. (1814). *Edinb. med. J.*, **10**, 50.

CHEST LEAD CHANGES AS THE SOLE ELECTRO-CARDIOGRAPHIC EVIDENCE OF HEART DISEASE

BY

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Within the past seven years the fourth lead, as originally introduced by Wolferth and Wood (1932) after the experimental studies of Wilson *et al* (1931), has been used with increasing frequency as a routine cardiographic procedure (Lieberson and Lieberson, 1932–33; Hoffmann and De Long, 1933; Katz and Kissin, 1933; Goldbloom, 1934; and Master, 1934). It has occasionally come to the fore as the exclusive sign of myocardial infarction involving the so-called "silent" areas of the heart, regions not adequately explored by the standard leads. Its value as the sole electrocardiographic sign of myocardial disease, not due to coronary thrombosis or sclerosis, has not received much attention. We therefore decided to review a large series of cardiograms to determine how often positive findings in the fourth lead are the only evidence of myocardial disease, i.e. where there are no revealing signs in the standard leads.

Four thousand four-lead cardiograms taken at Beth Israel Hospital from January 1, 1936, to January 1, 1939, were studied. Only those records were finally selected in which the standard leads were within normal limits and the præcordial leads were unquestionably abnormal as evidenced by (1) an absent R wave or an R wave of less than 2 mm., (2) a depressed or significantly elevated RS–T segment (2 mm. or more above the iso-electric line), (3) an M or W type of QRS complexes, or (4) inverted T waves—criteria which Wood and Wolferth (1939) have agreed to very recently. Observations on serial changes were not included as a part of this study.

METHOD AND RESULTS

The right arm electrode was placed 5 cm. to the left of the midsternal line in the fourth interspace. The other electrode was led off from the left leg. This derivation of the præcordial lead corresponds to the mirror image of the CF_3 lead which Wood and Wolferth (1939) in their most recent review consider very useful and reliable.* Small monel metal electrodes (1 inch in diameter) with salt paste were used.

* Since January 1938, following the suggestion of the American Heart Association, we have been taking the præcordial lead with the R–A electrode attached to the left leg and the L–A electrode to the præcordium. Throughout this paper the description of the præcordial lead is as if it were taken in this direction. In the figures both the old method of taking the electrocardiogram, and its mirror image, the new CF_3 lead, are shown.

Of the 4000 records studied, duplication reduced the total number of cases to be reviewed to 3200. Seventy of these (2·2 per cent) showed præcordial lead abnormality without significant changes in the standard leads. One third of this original group of 70 was finally chosen because of the completeness of clinical detail for analysis in the present study.

After thorough review of the clinical history, physical examination, and radiological findings, the 23 cases were divided into a cardiac and a non-cardiac group, details of which are shown in the tables.

Cardiac Group

The cardiac group consisted of 13 cases; 10 of these (77 per cent) were females. Details are shown in Fig. 1 and Table I. Only 1 had acute coronary

TABLE I

ELECTROCARDIOGRAPHIC FINDINGS IN 13 CARDIAC CASES

Diagnosis	Age and Sex	Axis Deviation and Changes in Standard Leads	Changes in Lead CF_3
1. Coronary thrombosis and empyema of gall bladder	62 F	Sl. depressed $RS–T_1$ Slurred QRS_2 *	Small R Slurred QRS
2. Coronary sclerosis and hypertension	58 F	Sl. slurred QRS_2 Inverted T_3 *	Absent R Cove-planed T Small QRS
3. Coronary sclerosis and hypertension	65 M	Slurred QRS_1 *	Absent R W-type QRS
4. Rheumatic mitral stenosis	18 F	Inverted P_3 Biphasic T_3	Inverted T
5. Arteriosclerotic heart disease	53 F	Inverted T_3 *	M-type QRS Inverted T
6. Essential hypertension	60 F	Sl. depressed $RS–T_2$ Small, biphasic T_3 *	Small QRS Inverted T
7. Essential hypertension and diabetes	38 F	Small QRS_3 Low, biphasic T_3.	Sl. elevated RS–T Rel. small R Sl. inverted T
8. Nephritis, hypertension, and pregnancy	41 F	Small QRS_3	Very small R Monophasic, slurred QRS
9. Luetic aortitis and cirrhosis	56 M	Slurred QRS $_{2 \text{ and } 3}$ Prominent S_2 *	Absent R Unusual QRS
10. Hyperthyroidism ..	64 M	Slight tachycardia *	Absent R, unusual QRS
11. Unknown cardiac disease	44 F	Q_2 and Q_3 present Slurred QRS	Inverted T Small, slurred QRS
12. Unknown cardiac disease	38 F	Low-voltage QRS_3 Inverted T_3	Absent R Monophasic QRS
13. Unknown cardiac disease	46 F	Low QRS_3	Small R Inverted T

* Left axis deviation.

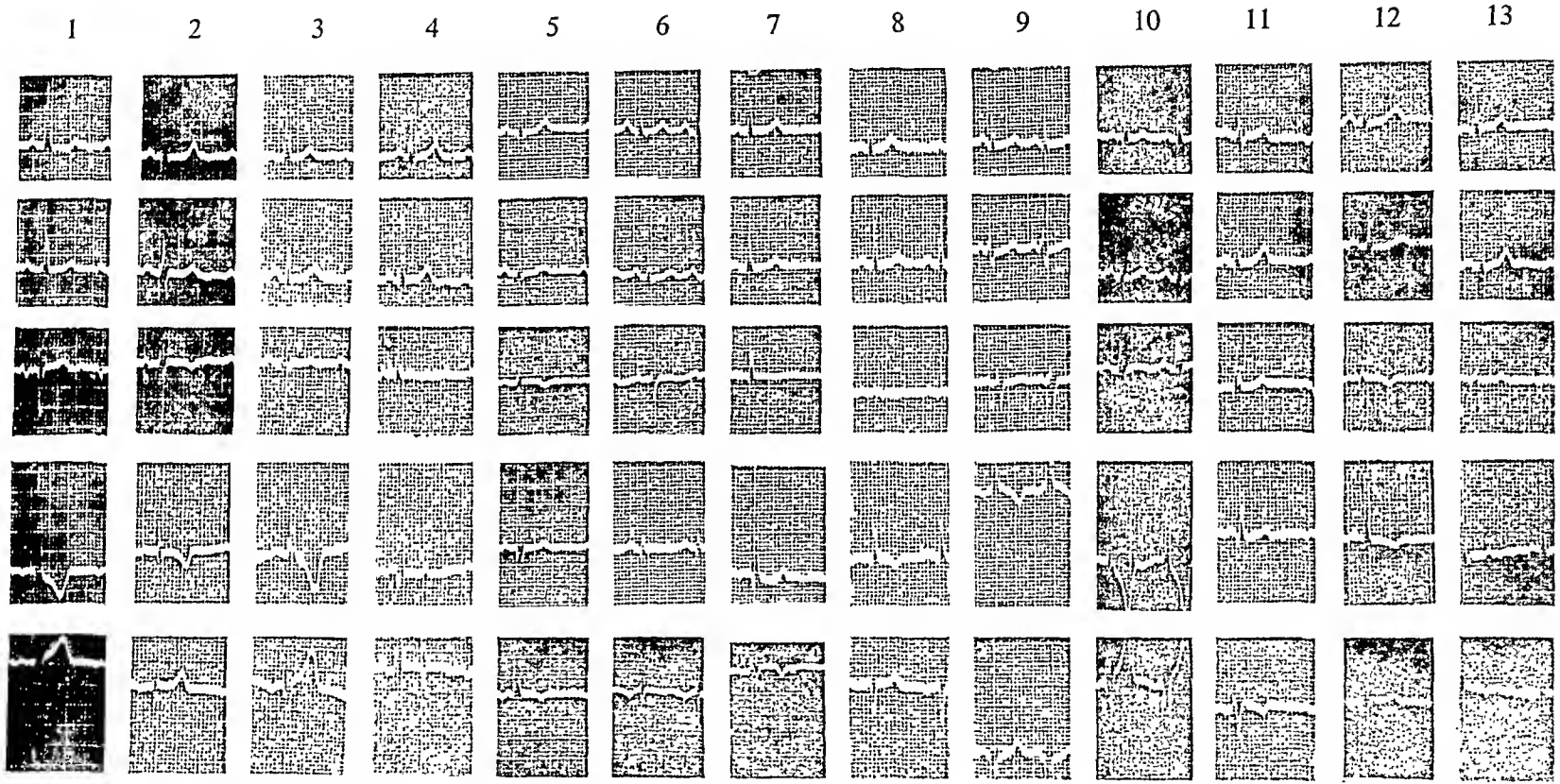

FIG. 1.—Electrocardiograms of the cardiac group of 13 patients with normal standard leads and abnormal chest leads. Note that the tracings in the bottom line marked CF_3 are the inverted mirror images of the præcordial tracings in the line above, taken by the method of Wolferth and Wood.

thrombosis, and only 2 others suffered from coronary sclerosis. Left axis deviation was present in 7 patients. The initial upward deflection (R wave) * was absent in 5 cases, 3 of which were accompanied by left axis deviation; it was small (less than 2 mm.) in 5 patients: in no case in which the R wave was absent was there an inverted T wave. QRS complexes of M and W type occurred in 2 cases. The T wave was inverted in 5 cases. All the 5 tracings in which the initial upward deflection (R wave) was small showed inverted T waves. In one patient a cove-planed T accompanied an almost absent R wave. *The most common finding in this cardiac group was an absent R wave* (38 *per cent*), *or a small R wave* (38 *per cent*).

Non-Cardiac Group

In this group of 10 cases (43 per cent), 8 were females. Diseases of the lungs contributed the greatest number of cases to this division. Details are shown in Table II and Fig. 2. Left axis deviation occurred in 4 cases. In contrast to the previous group the initial upward deflection (R wave) was absent only once (a man of 74 with adenocarcinoma of the sigmoid in whom coronary disease could not with certainty be ruled out clinically; for lack of positive evidence, however, we put him in the non-cardiac group). A small R wave occurred in 4 cases, and this was always accompanied by inverted or biphasic T waves. The T wave was inverted in 6 and biphasic in 3 cases. *Thus the characteristic positive finding of the non-cardiacs was T wave inversion.*

TABLE II

ELECTROCARDIOGRAPHIC FINDINGS IN 10 NON-CARDIAC CASES

Diagnosis	Age and Sex	Axis Deviation and Changes in Standard Leads	Changes in Lead CF_3
14. Carcinoma of left bronchus	45 M	Small $Q_{2 \text{ and } 3}$, low T_3 Slurred QRS, prom. S_1	Inverted T Slurred QRS
15. Broncho-pneumonia	50 F	Flat T_3	Low R Small, flat T
16. Broncho-pneumonia and diabetes	57 F	Slurred QRS Inverted T_3 †	Small inverted T Small QRS
17. Neoplasm of right lung	44 F	Sl. depr. $RS\text{–}T_{1, 2, 3}$ Low QRS_3	Low R Small inverted T
18. Pregnancy	29 F	M-shaped QRS, S_1 present, Inverted T_3	Inverted T
19. Pregnancy	21 F	Inverted T_3	Low biphasic T
20. Pylorospasm ..	54 F	Small QRS_3 Flat T_3	Small R Small inverted T
21. Chronic cholecystitis.	52 F	Sl. diphasic $T_{1, 2, 3}$ Q_3 present Small QRS_3 †	Small R Biphasic T
22. Adenocarcinoma of sigmoid	74 M	Sl. slurring $QRS_{2, 3}$ †	Absent R Cove-planed T
23. Spinal deformity and polyneuritis	18 F	Biphasic T_3	Inverted T

* See note on p. 13. † Left axis deviation.

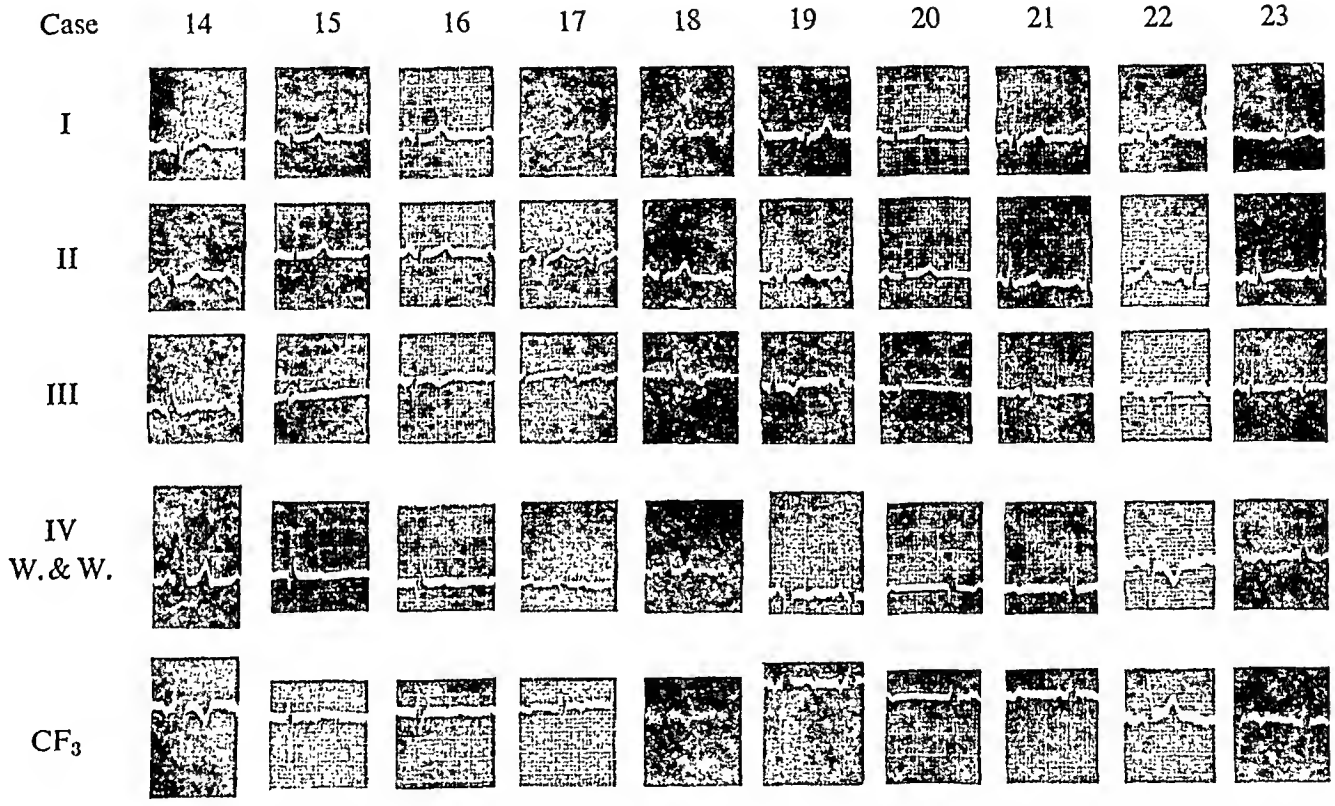

FIG. 2.—Electrocardiograms of the non-cardiac group of 10 patients with normal standard leads and abnormal chest leads. Note that the tracings in the bottom line marked CF_3 are the inverted mirror images of the præcordial tracings in the line above, taken by the method of Wolferth and Wood.

Discussion

To assay the significance of any lead in the diagnosis of heart disease is very difficult, since dogmatic statements in any single case cannot be made before necropsy is performed. With relatively limited autopsy material available, reliance had to be placed on clinical history, physical examination, and radiology (Note that for obvious reasons of logic, we could not even use the electrocardiograms in this study to help determine which of our cases were cardiac and which non-cardiac.) For this reason we have included in our analysis only those cases in which the charts were complete enough to give a full history and the physical and radiological features of the case. Where any doubt existed the patient was recalled for re-examination.

An analysis reveals that 5 of the 6 cases in which R_4 was absent were in the cardiac group, and the sixth, who was a man of 74, may well have had coronary sclerosis. It therefore follows that an absent R_4 is the most important single evidence of myocardial disease. We cannot, however, agree with Levine and Levine (1936) who consider an absent R_4 wave as positive evidence for myocardial infarction, since this condition was present in only 1 of our 5 cases with an absent R_4. As has been previously reported by Master *et al* (1937), this finding indicates heart disease in general, but does not determine the exact nature of the pathological process.

Further study of the 23 positive fourth lead cases showed that small R waves were seen as frequently in the non-cardiac as in the cardiac group. No significant T wave aberrations occurred in either group. We could not determine accurately whether or not small R waves or biphasic or inverted T waves in the fourth lead betokened myocardial damage, when the conventional leads were normal. The incidence of a small R wave in 5 cases of the cardiac and in 5 cases of the non-cardiac group suggests, however, that this single finding in the fourth lead does not indicate myocardial disease. As for the T_4 wave abnormalities, the chart shows 6 cases with inverted T waves in the cardiac, and 5 cases in the non-cardiac group. This agrees with Levine and Levine's report (1936) of inverted T waves in adults where there was no significant heart disease, and disagrees with Edeiken *et al.* (1936) who feel that adult cases showing an abnormal præcordial T wave as the only significant electrocardiographic finding have angina pectoris or a history of coronary occlusion.

The great number of females in both groups (18 out of 23, i.e. 78 per cent), seemed rather striking, in view of the fact that the præcordial lead changes have up to now been most frequently reported as accompanying coronary thrombosis or sclerosis—conditions which predominantly affect the male sex. (The ratio of more than 3 females to 1 male in this series differs from the general ratio of about 1 to 1, observed in this electrocardiographic department. No comprehensive reports comparing præcordial leads in males and females have been found. Shipley and Hallaran (1936) compared 200 normal men and women, but the ages varied from 20 to 35 years, whereas the mean age for the females of our series was 44 years. Since the cardiographic aberrations incident to pregnancy are reversible (Landt and Benjamin, 1936), we do not feel that

they could have played a significant role in this group, except possibly for Cases 18 and 19. Abdominal obesity, however, by causing changes similar to those that obtain in pregnancy may have been a factor in shifting the heart's axis, thus accounting for the T wave inversion.

Summary and Conclusions

Four thousand four-lead electrocardiograms (3200 cases) were reviewed to assess the diagnostic value of an abnormal præcordial lead when the standard leads were normal. The criteria adhered to as a basis for this selection were an absent R wave, an R wave of less than 2 mm., a QRS wave of M or W configuration, or an inverted T wave—these being found in the fourth lead, in the presence of standard leads that were without significant alterations. Of the 3200 cases 70 showed positive præcordial and negative standard leads. Of these 70 a characteristic group of 23 was completely analysed as representative of the larger group. By careful history, physical examination, and X-ray the 23 cases with positive chest leads were divided into a cardiac group (57 per cent) and a non-cardiac group (43 per cent). Left axis deviation occurred with about equal frequency in both groups. In the cardiac group, coronary thrombosis was present only once (8 per cent). Pulmonary disease contributed the greatest number of cases to the non-cardiac group (4 out of 10). *Absence of the initial upward deflection (R wave) in lead IV was the most common finding in the cardiac group (5 out of 13 cases).* Low R waves occurred with about equal frequency in both groups. Inverted or biphasic T waves were present slightly more often in the non-cardiac than in the cardiac group. The female sex was predominant in the ratio of about 3 to 1 in both groups.

Where the standard leads were normal the præcordial lead was the sole electrocardiographic indicator of heart disease in 1·2 per cent of 3200 cases studied. An abnormal fourth lead in the presence of normal standard leads is indicative of heart disease in more than 50 per cent of such cases.

An absent R wave is of greater significance as a sign of myocardial damage than are either low R waves or inverted T waves, alone or combined.

The præcordial lead may be the only electrocardiographic evidence of heart disease in conditions other than coronary thrombosis or sclerosis.

The authors are deeply indebted to Dr. Harry Vesell, Director of the Electrocardiographic Department, for his co-operation in this study; and to Mrs. F. Moore, the electrocardiographic technician, who helped to prepare the tracings for publication.

References

Edeiken, J., Wolferth, C. C., and Wood, F. C. (1936). *Amer. Heart J.*, **12**, 666.
Goldbloom, A. A. (1934). *Amer. J. med. Sci.*, **187**, 489.
Hoffman, A. M., and DeLong, E. (1933). *Arch. intern. Med.*, **51**, 947.
Katz, L. N., and Kissin, M. (1933). *Amer. Heart J.*, **8**, 595.
Landt, H., and Benjamin, J. E. (1936). *Amer. Heart J.*, **12**, 592.
Levine, D., and Levine, S. A. (1936). *Amer. J. med. Sci.*, **191**, 98.

Lieberson, A., and Lieberson, F. (1932–33). *Ann. intern. Med.*, 6, 1315.
Master, A. M. (1934). *Amer. Heart J.*, 9, 511.
——, Dack, S., Kalter, H. H., and Jaffe, H. L. (1937). *Amer. Heart J.*, 14, 297.
Shipley, R. A., and Hallaran, W. R. (1936). *Amer. Heart J.*, 11, 325.
Wilson, F. N., Barker, P. S., MacLeod, A. G., and Klostermyer, L. L. (1931–32). *Proc. Soc. exp. Biol. and Med.*, 29, 1006.
Wolferth, C. C., and Wood, F. C. (1932). *Amer. J. med. Sci.*, 183, 30.
Wood, F. C., and Wolferth, C. C. (1939). *Amer. Heart Assoc.*, 8, 1.

PULMONARY EMBOLISM: DIAGNOSIS BY CHEST LEAD ELECTROCARDIOGRAPHY

BY

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Limb lead electrocardiograms in cases of pulmonary embolism show characteristic changes, which have been carefully studied by Barnes (1937). The essential features are a tendency towards right axis deviation, with a constant S wave in lead I, and in lead III a moderate Q wave and sharp inversion of T. The appearances in lead III simulate posterior myocardial infarction, although Q is inconstant, and the R–T segment is rarely elevated and never markedly so. Fig. 1 shows three serial cardiograms from a case of massive pulmonary embolism proved at autopsy. During life this patient, who was originally put

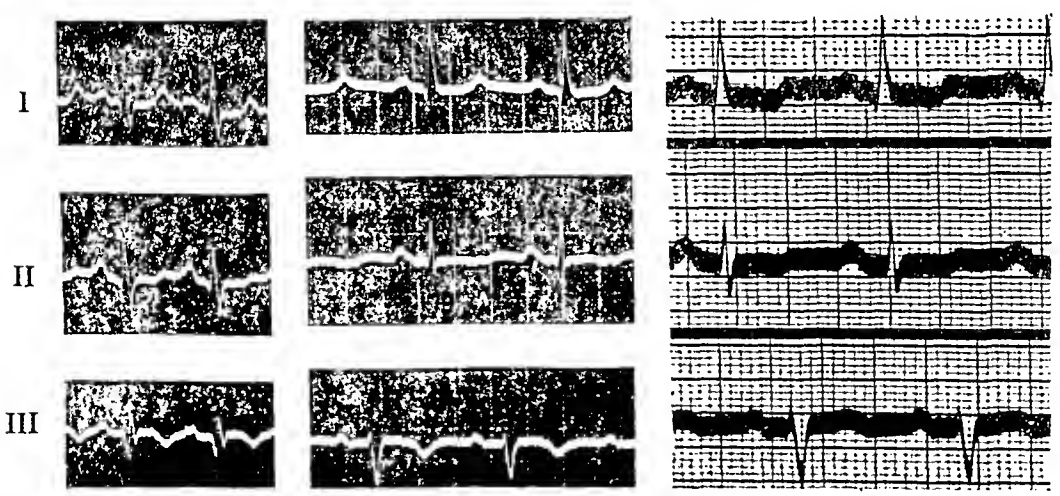


FIG. 1.—Serial limb lead electrocardiograms in a case of pulmonary embolism proved at autopsy. (The case was misdiagnosed as one of posterior infarction during life.) Case 1.

to bed for a rest on account of hypertensive heart disease, was wrongly diagnosed as posterior myocardial infarction. The differential diagnosis between these two conditions may usually be made by giving consideration to all the points tabulated by Barnes, but there are times when the distinction is difficult, if not

impossible. Further, on the clinical side, although as a rule the diagnosis of one or the other is not in doubt, there are occasions when there appear to be no distinguishing features. Substernal pain, a feeling of having been struck in the chest, tightness in the chest, breathlessness, faintness or loss of consciousness, profuse sweating, and prostration are symptoms common to both; while a small rapid pulse, a fall of blood pressure, gallop rhythm, and a cold, clammy, grey skin are signs common to both. Radiation of pain to the neck or arms, a change of cardiac rhythm, or true pericardial friction favour myocardial infarction; whereas an abrupt or early rise of venous blood pressure points to pulmonary embolism. Finally, in a series of 289 cases of pulmonary embolism found at autopsy to be the cause of post-operative death, a series in which as high a proportion as 82 per cent were correctly diagnosed in life, coronary occlusion headed the list of incorrect diagnoses (Nygaard, 1938). In another autopsy study of post-operative pulmonary emboli about two thirds of 229 cases were not diagnosed clinically (Prettin, 1936). Of pertinent interest is the series of 200 cases of coronary thrombosis reported by Eppinger and Kennedy (1938), for pulmonary embolism was found to be the cause of death in 6 per cent, and was present in 24 per cent. Belt (1939) especially has drawn attention to the fact that pulmonary emboli are as common amongst the patients in the medical wards as amongst those in surgical wards.

Enough has been said to make it clear that a more certain method of diagnosing pulmonary embolism is required, and that it should leave no room for confusion in distinguishing pulmonary embolism from posterior myocardial infarction. It is the object of this paper to present such a method.

Chest Lead Electrocardiograms in 10 Cases

Chest lead electrocardiograms have been used widely as an aid in the diagnosis of myocardial infarction. As we are concerned here only with the difficulty of distinguishing pulmonary embolism from posterior infarction, it is only necessary to refer to the chest lead appearances of such infarcts. As is now well known there may be no changes recorded, or there may be depression of the RS–T segment with an upright T wave, or there may be very tall T waves, but there is never inversion of the T wave in any chest lead (Wood and Selzer, 1939). Examples of the two latter changes are shown in Figs. 2 and 3 (p. 24).

During the last few years at Hammersmith Hospital chest lead cardiograms have been taken on all suspected cases of pulmonary embolism and have been found very helpful. Ten cases are presented in Table I, compiled in order to show upon what evidence the diagnosis was made. Only those cases with considerable obstruction of the pulmonary circulation have been included, for it was found that small emboli insufficient to throw any stress on the right ventricle produced no changes in the electrocardiogram and in no way imitated myocardial infarction. Further, all these cases necessarily lived long enough for serial cardiograms to be taken, with one exception that is only included

TABLE I.—DETAILS OF THE TEN CASES

Case No.	Sex and Age	Diagnosis and Cause of Embolism †	Clinical Features: all showed Dyspnoea and Pallor														Proof of Embolism
			Recurrent Attacks	Pain / Tightness } Substernal	Syncope	Blood Pressure	Pulse Rate	Sweats	Cyanosis	Engorged Cervical Veins	Hepatic Enlargement	Right Ventricular Gallop	Pulmonary Consolidation (C), Haemoptysis (H), or X-Ray Opacity (X)	Pleural Pain	Pleural Friction	Haemorrhagic Pleural Effusion	Clinical (C), Operative (O), or Autopsy (A)
1	F., 63	Hypertensive heart disease	−	+	−	—		+	±	+	+	+	H	−	−	−	A
2*	M., 63	Appendicectomy, 10th day †	+	+ +	+	145/80	95	+	±	−	−	−	−	−	−	−	C
3	F., 38	Pyelitis †	+	− +	+	90/70	144	+	+	+	+	+	H	+	+	+	C
4	M., 49	Perforated duodenal ulcer: post-operative †	+	− −	−	90/75	140	+	+	+	+	+	CH	+	+	−	C
5	M., 35	Gastric ulcer: post-operative	+	− −	−	100/80	130	−	+	+	−	−	CX	+	−	−	C
6*	M., 20	Mild injury to leg †	+	− −	−	140/80	115	+	−	−	−	−	X	+	−	−	C
7*	F., 34	Cervicitis †	−	− +	+	—	120	+	±	−	−	−	−	−	−	−	−
8	F., 53	Carcinoma of rectum	−	− −	+	80/60		+	±	+	−	−	−	−	−	−	OA
9	F., 43	Partial hysterectomy for fibroids	+	+ −	+	80/60	150	+	−	+	−	−	−	−	−	−	OA
10	M., 25	Mitral stenosis	+	− +	−	95/70		+	+	+	+	−	H	−	−	−	A

* Not seen by the author within three days of the onset.

† Deep femoral venous thrombosis, as evidenced by œdema of the limb, was the cause in all these cases except in Case 7, where it was due to a pelvic injection of anæsthetic oil, proctocaine.

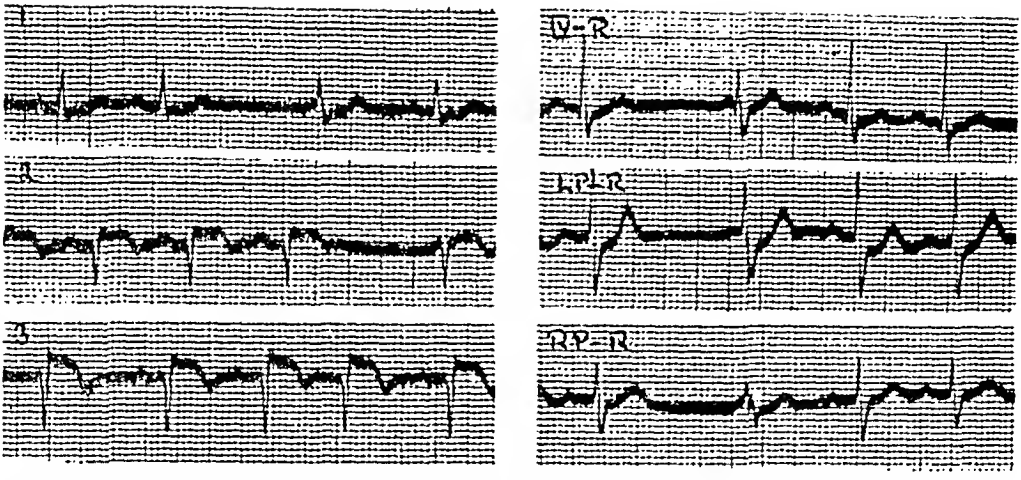


FIG. 2.—Depression of the RS-T segment is seen in the left pectoral lead in this case of posterior myocardial infarction.

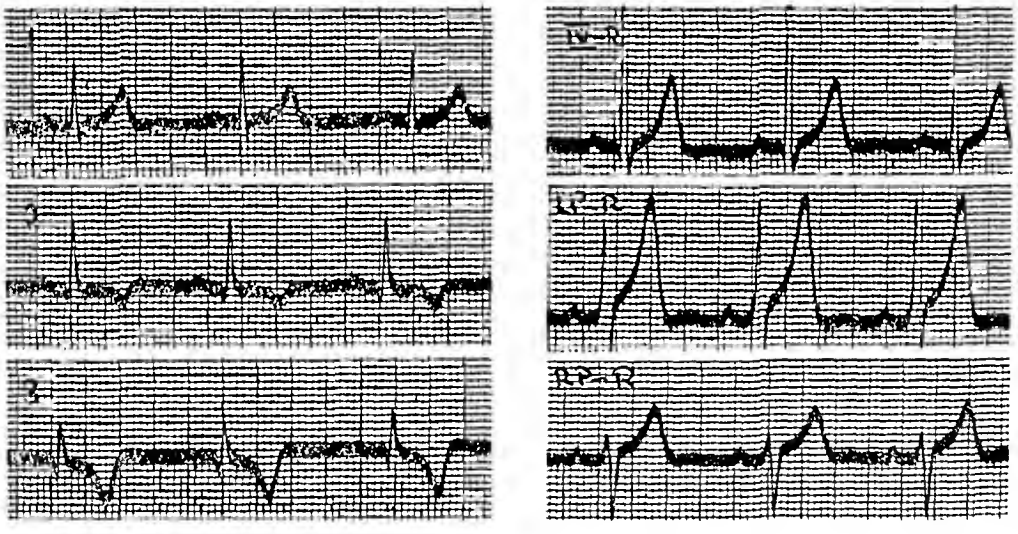


FIG. 3.—Posterior myocardial infarction with very tall T waves in the left pectoral lead.

to show that the changes take time to develop. I have encountered no reasonably proved case of pulmonary embolism with evidence of right ventricular stress that failed to show the changes about to be described, provided life was not extinguished too quickly.

Multiple chest lead cardiograms were taken from the apex beat (lead IV), from the fourth right intercostal space at the right border of the sternum (right pectoral : RP–R), and from a point midway between these two (left pectoral : LP–R). The illustrations show lead IV on top, the left pectoral lead below it, and the right pectoral lead at the bottom (Wood and Selzer, 1939). The proximal electrode was always paired with the right-arm electrode, so that the apical lead was lead IV R.

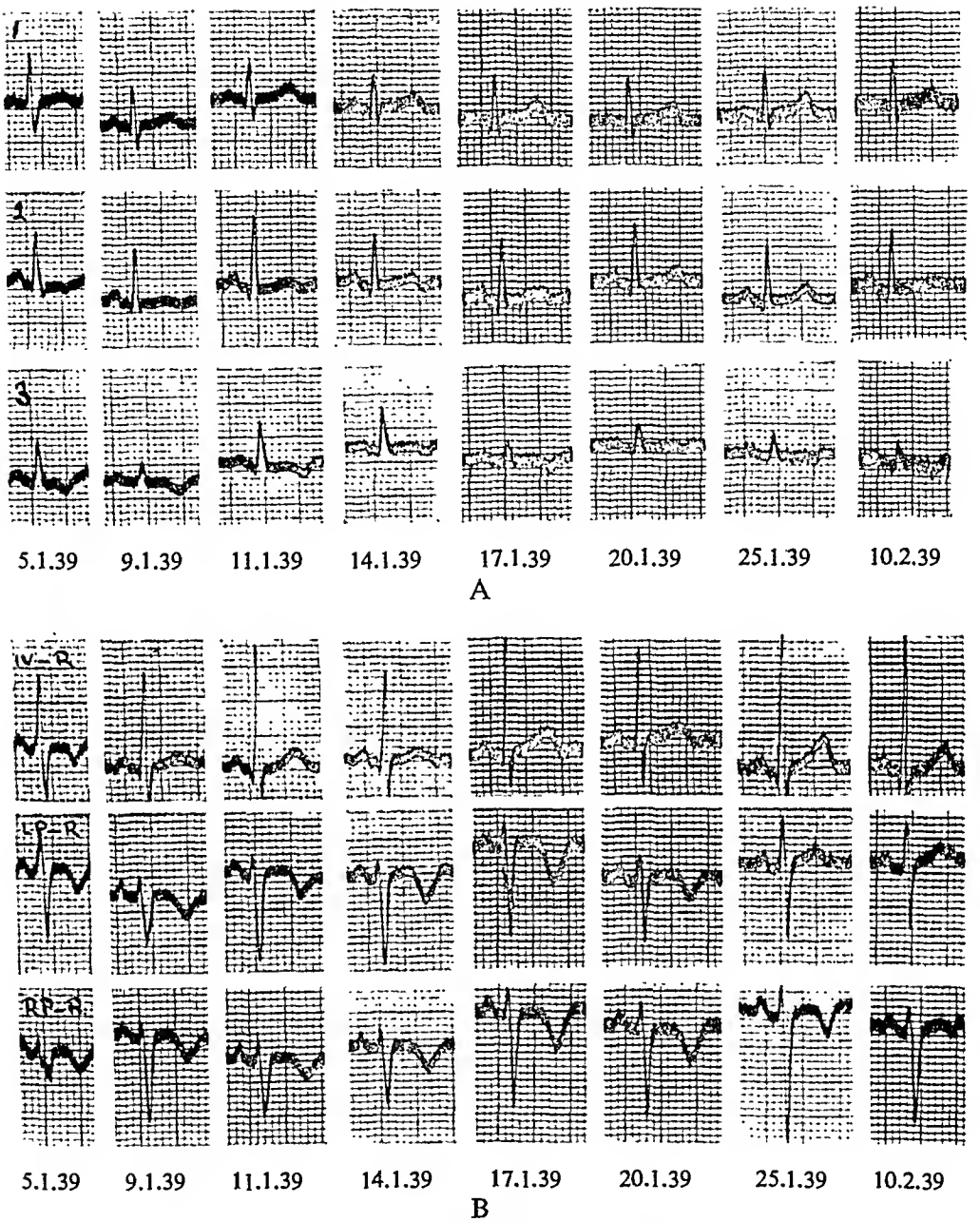
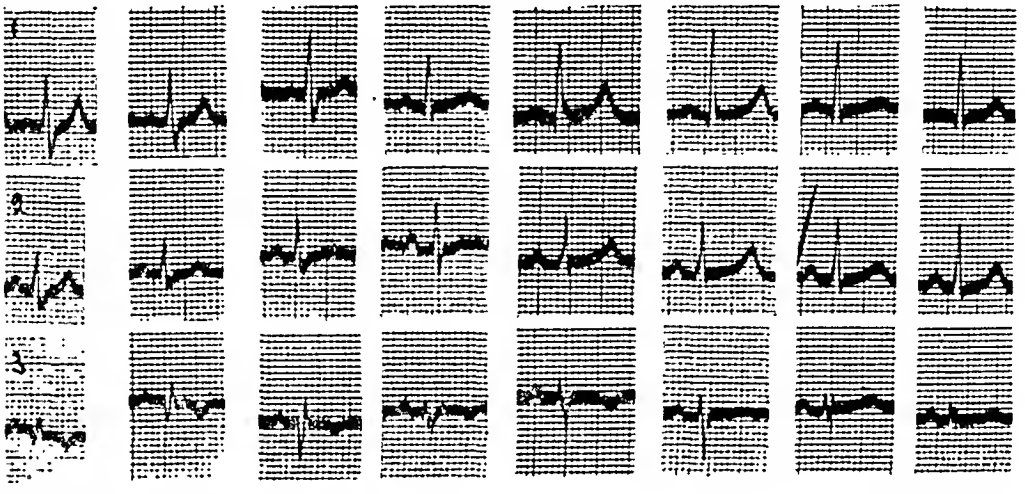


FIG. 4.—Serial electrocardiograms from a case of pulmonary embolism (Case 4).
(A) Limb leads, showing changes in T_2 of short duration and in T_3 of longer duration
(B) Chest leads, showing T inversion of long duration in LP–R and RP–R.

Fig. 10 (Wood and Selzer, 1939) and Figs. 4 and 5 show the diagnostic changes discovered in three typical cases (Cases 3, 4, and 5). The essential feature is sharp inversion of the T wave, without appreciable displacement of the RS–T segment, always in the right pectoral lead, usually but for a shorter duration in the left pectoral lead, and sometimes and for the shortest duration in lead IV. Less essential is a tendency for the QRS deflection to be mainly upwards in the right pectoral lead. The T wave commonly remains inverted

for several weeks in the right pectoral lead, for a week or two in the left pectoral lead, and for a day or two, if at all, in lead IV. These facts may be verified by examination of the dates of the serial cardiograms in the examples shown. It is, however, easier to follow the stages of recovery than the stages of develop-



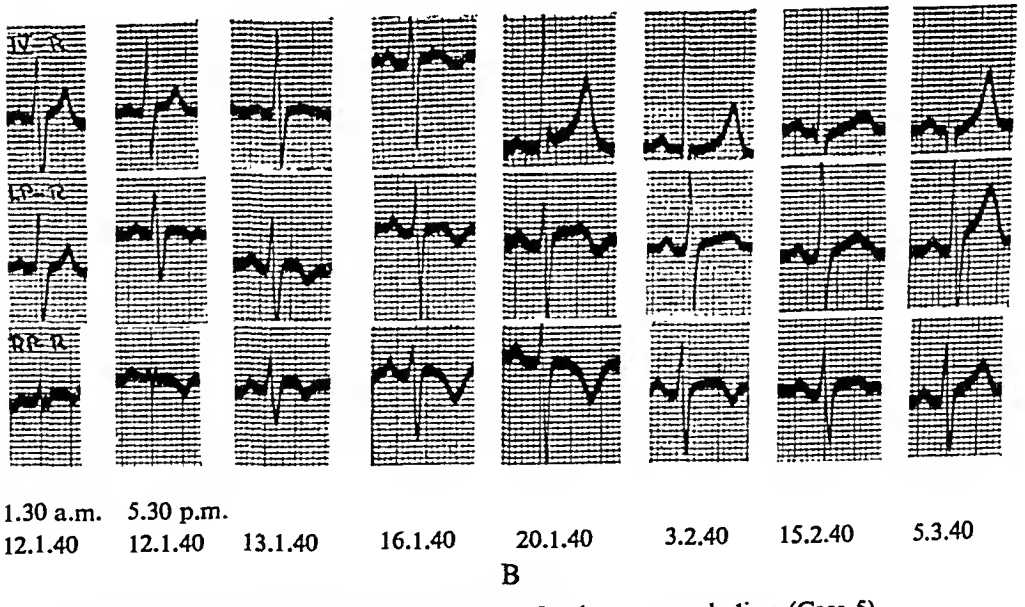


FIG. 5.—Serial electrocardiograms from a case of pulmonary embolism (Case 5).
(A) Limb leads, showing T_3 inversion.
(B) Chest leads, showing the maximum change about the fourth to eighth day.

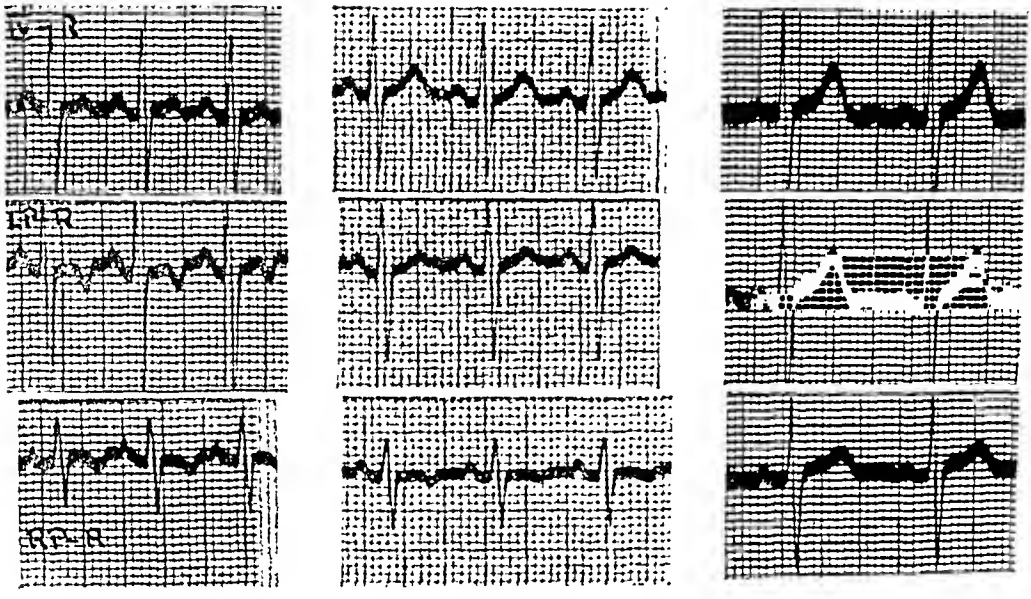
ment. Case 8 died one hour after the event, and the cardiogram that was taken within a half hour shows no change. In Case 5 (Fig. 5) the initial cardiogram was recorded within a few hours after the onset, and it will be seen that changes are minimal; six hours later they are still developing, and on the following day

they are established. Only regressive changes were observed in all the other cases, although in six of the eight the first cardiogram was taken within six to twenty-four hours after the onset. It appears, therefore, that maximal changes occur in a few hours but are not immediate.

Discussion

It has been argued that the limb lead changes indicate myocardial ischæmia because they imitate those of posterior myocardial infarction (Parsons-Smith, 1940). This ischæmia is thought to be due to shock, to anoxæmia, or to reflex coronary vaso-constriction. Further, Scherf and Boyd (1939) point out that the right ventricle would be especially embarrassed by myocardial ischæmia because of the burden thrown upon it by the obstruction in the pulmonary circulation. These views are open to criticism. First, although the limb lead cardiogram may imitate the features of posterior myocardial infarction, the chest lead appearances are entirely different; this argument must therefore lapse. Second, it has not been shown that shock alone is capable of producing cardiographic changes of the kind under discussion. While it is not denied that shock may influence the symptoms of pulmonary embolism, there is no reason to believe that it is any more responsible for the cardiographic changes than it is in cases of myocardial infarction. Third, reflex coronary vaso-constriction is said to be independent of the size of the pulmonary embolus (Scherf and Schönbrunner, 1937): these authors described two cases with marked cardiographic changes following small pulmonary emboli, and witnessed a typical electrocardiograph pattern as a result of small experimental emboli in three out of ten dogs.

Yet, in the present series, the cardiographic changes appeared to depend very much upon the size of the embolus, and ran parallel to the development of acute cor pulmonale. Reference to the table will show that engorgement of the cervical veins was noted in seven out of the ten cases, and in each of these I made the observation myself within twenty-four hours of the onset. In the other three I failed to see the patient before at least three days had elapsed, and it is well known that the sign is apt to be overlooked unless special attention is paid to it. I have carefully examined many cases of pulmonary embolism within twenty-four hours of the event, and have not seen the cardiographic changes described above in the absence of evidence of acute cor pulmonale. It follows that, in the majority of cases, coronary vaso-constriction cannot be held responsible for these cardiograms unless it be associated with acute cor pulmonale. But if acute right ventricular stress from any cause can be shown to produce a similar cardiographic pattern, then it would seem that the theory of coronary vaso-constriction is not required to explain them. This appears to be the case. Selzer and I (1939) have recorded similar features, but in a persistent form, in pulmonary stenosis, mitral stenosis, and chronic cor pulmonale; transient changes, indistinguishable from those produced by pulmonary embolism, are found in rheumatic carditis (Wood, 1939), diphtheria



12.4.39 18.4.39 1.12.39

FIG. 6.—Limb and chest lead electrocardiograms from a case of pneumonia. The serial chest lead records are indistinguishable from those of pulmonary embolism. The standard leads taken on the same dates showed some inversion of T in lead III which gradually diminished and disappeared.

(Pincus, 1939), and pneumonia (see Fig. 6), conditions known to be associated with isolated right ventricular failure.

It is concluded that the essential factor in the production of these changes is right ventricular stress. It is not unlikely that the explanation when discovered will be the same as that for T wave inversion in leads I and IV in cases of left ventricular stress, e.g. in hypertensive heart disease, when T in lead I inversion may be found associated with widely dilated coronary arteries (Harrison and Wood).

The same argument may be used to show that the chest lead electrocardiograms described, although providing a good method for the differential diagnosis between pulmonary embolism and posterior myocardial infarction, are not in themselves diagnostic of pulmonary embolism, but of acute and transient right ventricular stress. They bear the same significance as does a rise in systemic venous blood pressure, but whereas the latter may last only a few hours or days, the cardiographic pattern usually persists for weeks.

SUMMARY

1. Acute pulmonary embolism may be difficult to distinguish from posterior myocardial infarction, both clinically and by means of limb lead electrocardiograms.

2. Multiple chest lead cardiograms afford a good method of differential diagnosis.

3. In posterior myocardial infarction, as is well known, there may be no cardiographic change, or the RS–T segment may be depressed, or the T waves may be very tall.

4. In pulmonary embolism sufficient to cause right ventricular stress there is sharp inversion of the T wave, maximal and for the longest duration in the right pectoral lead; usually, but for a shorter duration, in the left pectoral lead; and rarely, and for the shortest duration, in lead IV.

5. Similar changes may be found in all conditions giving rise to right ventricular stress.

My thanks are due to Dr. Daley, chief medical officer of the London County Council, for his permission to publish these cases.

REFERENCES

Barnes, A. R. (1937). *J. Amer. med. Ass.*, **109**, 1347.
Belt, T. (1939). *Lancet*, **1**, 1259.
Eppinger, E. C., and Kennedy, J. A. (1938). *Am. J. med. Sci.*, **195**, 104.
Harrison and Wood. To be published.
Nygaard, K. K. (1938). Meet. Mayo Clinic, 1938, **13**, 586.
Parsons-Smith, B. T. (1940). *Brit. med. J.*, **2**, 179.
Pincus, J. V. (1939). *Personal communication on work to be published.*
Prettin, F. (1936). *Virchows Arch. f. Path. Anat.*, **297**, 535.
Scherf, D., and Boyd, L. J. (1939). *Cardiovascular Diseases*, St. Louis.
—— and Schönbrunner, E. (1937). *Klin. Wchnschr.*, **16**, 340.
Wood, P. (1939). *Chest Lead Electrocardiography.* Thesis Univ. Melb.
—— and Selzer, A. (1939). *Brit. Heart J.*, **1**, 49.

T WAVE INVERSION, HEART SIZE, AND FUNCTIONAL CAPACITY

THE CORRELATION BETWEEN THESE IN 100 PATIENTS WITH HYPERTENSION

BY

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T wave inversion and RS–T segmental deviation have been emphasized as evidence of myocardial infarction and coronary disease. It is not, however, rare to encounter these changes in tracings of those who do not exhibit the clinical picture of these conditions—the only demonstrable pathology being enlargement. Barnes and Whitten (1929), on careful post-mortem examination, were unable to detect gross or microscopic damage to the myocardium in a large series of cases presenting these electrocardiographic findings. Master (1939) and Barnes (1940) have noted progressive changes in the T wave and RS–T segment as enlargement proceeds; they contend there is a characteristic configuration for relative preponderance of one or the other ventricle, and have suggested the term " ventricular preponderance or strain " for use in cardiographic interpretation.

An investigation was undertaken, in the attempt (1) to correlate these changes with the degree of enlargement of the heart and with functional capacity; (2) to determine whether the cardiographic pattern is sufficiently characteristic and clinically valuable to warrant its retention; and (3) to determine the types of heart disease associated with " left ventricular preponderance."

Material and Criteria

One hundred consecutive clinic and hospital patients with hypertension were the subjects of this study. The series included white and coloured patients and Mexicans, of all ages and both sexes. Five were classified clinically as malignant hypertension (nephrosclerosis) and the remainder as essential hypertension. There was unequivocal evidence of over-digitalization in four, and of recent coronary occlusion in five.

Patients with blood pressures above 150/90 determined by the method prescribed by the American Heart Association and the Cardiac Society of Great Britain and Ireland (1939) were considered to have hypertension and were included in this series.

The standard leads of the cardiogram of each patient were studied for axis deviation, amplitude of the QRS complex, RS–T segmental deviation, and T wave direction. The angle of direction of the electrical axis was determined

by the method devised by Einthoven (1908), and further developed by Carter, Richter, and Greene (1919). The amplitude of QRS was counted as increased if the R or S wave or both were 15 mm. or more. The RS–T segment or T take-off was considered displaced if it was 0·5 mm. or more from the isoelectric line. The criteria for left ventricular preponderance were (1) left axis deviation, (2) negative T_1, or T_1 and T_2, with a positive T_3, and (3) the negative T arising from the S wave, 0·5 mm. or more below the isoelectric line, or from a depressed RS–T segment.

In 55 cases the cardiac size was measured by the cardiothoraic ratio determined by teleo-radiography. A ratio below 50 per cent was considered normal, 50–54 per cent slightly enlarged, 55–61 per cent moderately enlarged, and 62 per cent and above extremely enlarged. In the remainder of the cases enlargement was determined clinically. If the apex beat was palpable in the fifth intercostal space within the midclavicular line, the size was considered to be within normal limits; from the midclavicular to the nipple line slightly enlarged; from the nipple to the anterior axillary line or in the sixth intercostal space, moderately enlarged; and at or beyond the anterior axillary line or in the seventh intercostal space, extremely enlarged.

Classification of functional capacity was determined from the history and physical examination according to the criteria of the American Heart Association as laid down in the *Nomenclature for Criteria for Diagnosis of Diseases of the Heart* (1939).

Correlation of Functional Capacity with Cardiac Enlargement

The clinical impression of a positive correlation between the size of the heart and the functional capacity is confirmed by Table I. Were it not for the accidents occurring in the course of hypertensive heart disease (coronary occlusion, arrhythmias, and conduction disturbances), the correlation would probably be even more complete.

Table I.—Correlation of Functional Capacity with Cardiac Enlargement

Size of Heart	Functional Capacity				Total
	I	II	III	IV	
Normal	7	7	—	—	14
Slightly enlarged..	1	10	5	3	19
Moderately enlarged	—	3	14	15	32
Externally enlarged	—	—	4	31	35
Total	8	20	23	49	100

Correlation of T Wave Direction and RS–T Segmental Deviation with Cardiac Enlargement

Typical electrocardiograms from patients with hypertension, with varying degrees of enlargement of the heart, are shown in Fig. 1. Other authors have

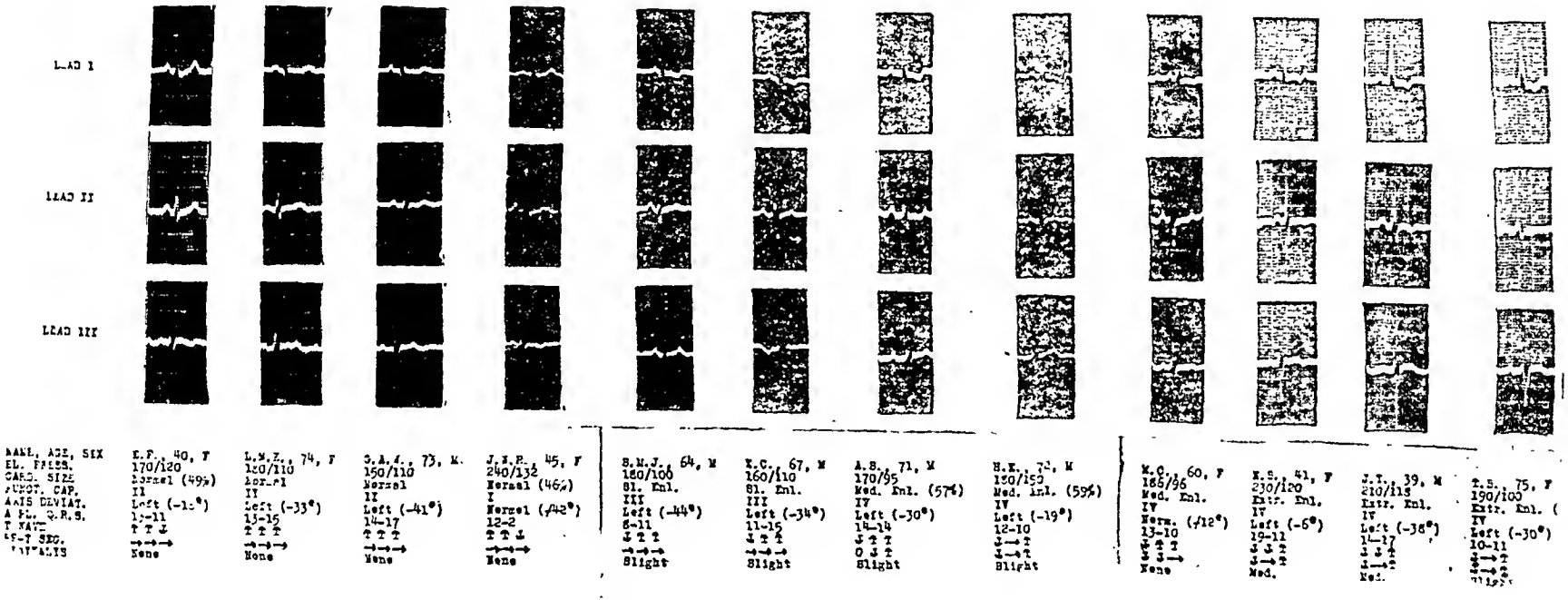

FIG. 1.—*Common types of electrocardiograms in hypertensive heart disease with various degrees of cardiac enlargement.*

published tracings showing similar progressive changes in individual patients as the enlargement progressed.

In lead I the T wave tended to become inverted as the heart increased in size; 75 per cent of extremely enlarged hearts had inverted T waves, whereas there was no case of inversion in a normal-sized heart. The RS–T segment tended to become depressed as enlargement progressed, but this occurred less frequently than T wave changes, as approximately 50 per cent of extremely enlarged hearts had depressed RS–T segments or low T take-offs.

In lead II the T wave and RS–T segments both tended to become inverted as enlargement progressed. However, it only occurred half as frequently as in lead I. Its presence was more likely to signify moderate to extreme enlargement than final deflection changes limited to lead I.

In lead III 57 per cent of normal-sized hearts had inverted T waves. As enlargement progressed there was less tendency to inversion; 28 per cent of extremely enlarged hearts had inverted T waves. The tendency to positivity of T wave was mirrored in the RS–T segment, which became elevated as enlargement progressed. More detailed results with figures and tables follow.

T Wave

Lead I—The T wave was upright in all normal-sized hearts. But 37 per cent of slightly and moderately enlarged hearts had inverted T waves, and this was true in 74 per cent of extremely enlarged hearts. 45 per cent of the entire series had negative T waves.

Lead II—Here again no negative T waves were found in normal-sized hearts. There was inversion in 20 per cent of slightly and moderately enlarged hearts, whereas in extremely enlarged hearts, there was 57 per cent inversion. Of the entire series, the T wave was negative in 31 per cent.

Lead III—The T wave was inverted in 57 per cent of hearts of normal size, in 37 per cent of slightly enlarged, and in 24 per cent of moderately and extremely enlarged hearts.

These results are illustrated in Fig. 2.

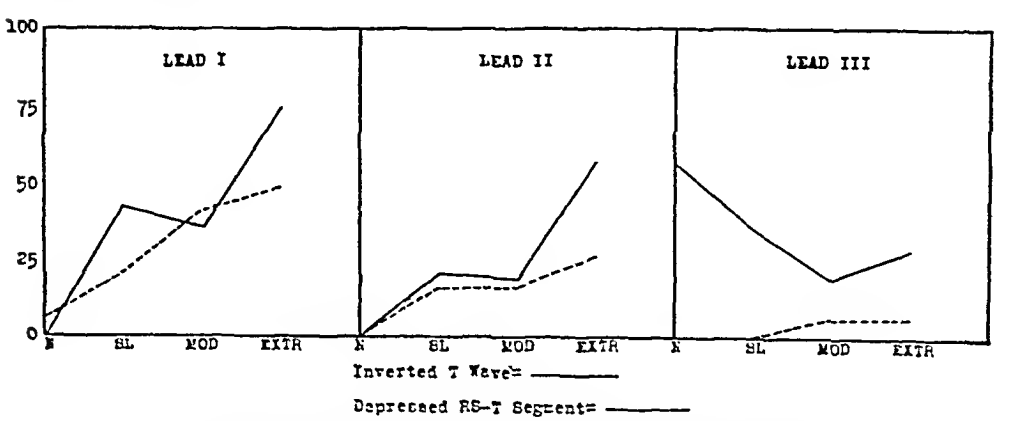

FIG. 2.—Correlation of heart size with inversion of T waves and depression of the RS–T segment in standard leads, expressed as percentages.

N indicates normal-sized, SL slightly, MOD moderately, and EXTR extremely, enlarged hearts.

RS–T Segment

Lead I—Of those with hypertension and normal-sized hearts 7 per cent had depressed RS–T segments. (One patient had a posterior coronary occlusion; another with positive RS–T segment had an anterior occlusion.) In slightly and moderately enlarged hearts, 33 per cent had depressed RS–T segments or low T take-off, whereas this was present in 48 per cent of extremely enlarged hearts. 35 per cent of the entire series had a low T take-off or a depressed RS–T segment.

Lead II—There was no deviation of the RS–T segment in any of the normal-sized hearts, whereas 16 per cent of the slightly and moderately enlarged hearts, and 26 per cent of the extremely enlarged hearts had depression of the RS–T segment.

Lead III—Of the normal-sized hearts 7 per cent had elevated RS–T segments, whereas in slightly enlarged it was 11 per cent, in moderately enlarged 22 per cent, and in extremely enlarged hearts 23 per cent.

Correlation of Left Axis Deviation, Amplitude of QRS, and Left Ventricular Preponderance with Cardiac Enlargement

Left axis deviation—There appears to be no positive correlation between the degree of cardiac enlargement and the angle of deviation of the electrical axis, or the frequency of left axis deviation; 64 per cent of normal, 53 per cent of slightly enlarged, 50 per cent of moderately enlarged, 65 per cent of extremely enlarged hearts, and 58 per cent of the entire group showed left axis deviation. Right axis deviation did not occur in this series. These results are given in Table II and Fig. 3.

Table II—Correlation of Cardiac Enlargement with Left Axis Deviation, Increased Amplitude of QRS, and Left Ventricular Preponderance

	Normal Size	Degree of Enlargement			Total
		Slight	Moderate	Extreme	
Left axis deviation (L.A.D.) ..	9	10	16	23	58
L.A.D. with high amplitude ..	4	2	10	3	19
L.A.D. with T_1 inverted and T_3 upright	—	4 (1)*	8 (2)	5 (2)	17
L.A.D. with T_1 and T_2 inverted and T_3 upright	—	2 (1)	2 (2)	9 (4)	13
Complete left ventricular preponderance	—	6	10	14	30
Total cases	14	19	32	35	100

* Figures in brackets refer to number of cases showing increased amplitude of QRS.

Increased Amplitude of QRS—31 per cent of the entire series showed an increased amplitude of QRS: 28 per cent of the normal, 21 per cent of the slightly enlarged, 43 per cent of the moderately enlarged, and 26 per cent of extremely enlarged hearts had increased amplitude. Again, there is no positive correlation and its frequency does not appear related to the degree of enlargement (see Fig. 3).

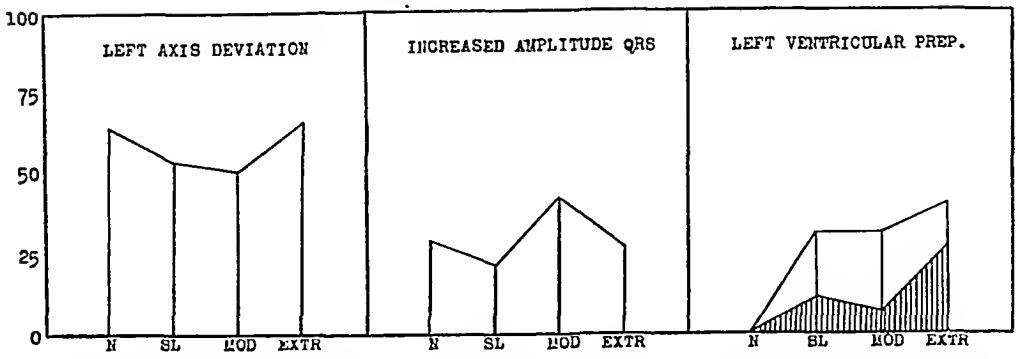

FIG. 3.—Correlation of heart size with left axis deviation, increased amplitude of QRS, and left ventricular preponderance, expressed as percentages.

In the right-hand third of the figure, the light area indicates T_1 inverted and T_3 upright; and the shaded area, T_1 and T_2 inverted and T_3 upright.

Left Ventricular Preponderance—No patient with a normal-sized heart exhibited left ventricular preponderance: 31 per cent of slightly and moderately enlarged and 40 per cent of extremely enlarged hearts showed preponderance. As the heart increased in size there was an increase in the frequency of occurrence of left ventricular preponderance, inversion of T_2, and depression of RS–T_2 segment (see Fig. 3). The slight proportionate increase of high amplitude QRS occurring with preponderance in the larger hearts appears not to be statistically significant; 30 per cent of the entire series had left ventricular preponderance. If the normals were eliminated, the frequency of left ventricular preponderance in enlarged hypertensive hearts was 35 per cent.

ÆTIOLOGY OF CARDIAC ENLARGEMENT IN LEFT VENTRICULAR PREPONDERANCE

Hypertension (82 per cent) was the most common ætiological factor associated with left ventricular preponderance. Lues (15 per cent) was next in frequency (see Table III). The patient with rheumatic fever had marked mitral regurgitation with left ventricular enlargement. Possibly the case of arteriosclerosis should be listed under (pre-existing) hypertension, since the patient had a pressure of 140/80, was in marked congestive failure, had extreme enlargement of the heart, and died eight days later. It appears that the electrocardiographic pattern described as left ventricular preponderance occurs only in those diseases of the heart that lead to enlargement of the left ventricle.

TABLE III

ÆTIOLOGY OF HEART DISEASE IN 60 CASES OF LEFT VENTRICULAR PREPONDERANCE

	Number of Cases	Percentage of Total
Hypertension	42	70·0
Hypertension and lues	6	10·0
Hypertension and emphysema ..	1	1·7
Lues	9	15·0
Rheumatic fever	1	1·7
Arteriosclerosis	1	1·7
Total	60	100·0

Summary and Conclusions

(1) The electrocardiogram, functional capacity, and cardiac size were correlated in a study of 100 consecutive patients with hypertension. There is a positive correlation between the size of the heart and functional capacity.

(2) As the heart enlarges in hypertension, the T wave progressively becomes inverted in leads I and II and upright in lead III. The RS–T segment follows the T wave in its direction.

(3) Left ventricular preponderance is a characteristic electrocardiographic pattern occurring in 35 per cent of patients with enlarged left ventricles. It occurs with increasing frequency as the heart enlarges, and is characterized by (1) left axis deviation, (2) inversion of T_1 or of T_1 and T_2 with T_3 upright, and (3) a depressed RS–T segment in lead I or in leads I and II and an elevated RS–T segment in lead III.

(4) Since functional capacity and cardiac size are both directly related to left ventricular preponderance, one may estimate, with some degree of accuracy in many cases, the functional capacity and approximate size from the electro-cardiographic picture.

(5) Because depressed RS–T segments in leads I and II and elevated RS–T in lead III are found in 35 per cent of enlarged hypertensive hearts, and this deviation is one of the cardinal patterns of posterior coronary occlusion, one should be extremely careful in making the latter diagnosis on the cardiographic evidence alone. The origin of the RS–T take-off and the presence of Q waves are of value in the differential diagnosis.

(6) Hypertension is the most frequent ætiological cause of left ventricular preponderance. Lues is the next most common ætiological factor.

(7) There is no positive correlation between the level of the blood pressure and these changes. Our data do not solve the problem of whether the duration of hypertension, enlargement *per se*, or some other factor associated with enlargement is responsible for the T and RS–T changes.

(8) We do not believe the few cases of coronary occlusion or over-digitalization in the series affect the general conclusions.

Acknowledgment is made to Dr. Ghent Graves for helpful suggestions, and to Dr. G. C. Lechenger of the Jefferson Davis Hospital for use of the radiological material.

References

Barnes, A. R. (1940). *Electrocardiographic Patterns.* C. C. Thomas. Phila.
—— and Whitten, M. B. (1929). *Amer. Heart J.*, **5**, 14.
Carter, E. P., Richter, C. P., and Greene, C. H. (1919). *Bull. J. Hopkins Hosp.*, **30**, 162.
Einthoven, W. (1908). *Arch. f.d. ges. Physiol.*, **122**, 517.
Master, A. M. (1939). *The Electrocardiogram and X-ray Configuration of the Heart.* Lea and Febiger. Phila.
Nomenclature for Criteria for Diagnosis of Diseases of the Heart (1939). J. J. Little and Ives. N.Y.
Standardization of Methods of Measuring Arterial Blood Pressure (1939). *Brit. Heart J.*, **1**, 261, and *Amer. Heart J.*, **113**, 294.

ATRIAL SEPTAL DEFECT

BY

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Patent foramen ovale and atrial (or auricular) septal defect (*A.S.D.*), though both characterized by an aperture in the atrial septum, are embryologically and pathologically different conditions.

Slit patency of the foramen ovale (to probe or even to pencil) is a commonplace in a normal atrial septum. As it should close during the first year of life, the patent foramen ovale is scarcely to be regarded as a congenital cardiac lesion, but rather as an anatomical variation of a pre-existent condition (Costa, 1931). It is present in 20–30 per cent of all necropsies (Thompson & Evans, 1930; McGinn & White, 1936; O'Farrell, 1938), and it is clinically silent. In exceptional circumstances an increase in the right atrial pressure during hypertensive cardiac failure (Marchal, Ortholan, & Breton, 1939) or in mitral stenosis (Lutembacher, 1916, 1936) can open up the slit foramen (" widely patent ") and determine or accentuate a terminal cyanosis. Pulmonary infarction may similarly enlarge the slit foramen and so facilitate the passage of a paradoxical embolus (Barnard, 1930; Thompson & Evans, 1930; Jones, 1936; Löfgren, 1937; Hirschboeck, 1935; Koritschoner, 1936). Terminal cyanosis and paradoxical embolism are the only two events referable to this common condition—a slit or widely patent foramen ovale—and they are rare.

In contrast, an atrial septal defect is a malformation that is really congenital. The development of the atrial septum by the union of three incomplete septa, namely, the septum primum (or superius), the septum secundum, and the septum intermedium, leaves pervious first the foramen ovale primum and later the foramen ovale secundum. The latter, narrowed by the septum secundum and provided with a membrane by the septum primum, becomes the fossa ovalis.

Atrial septal defect is the most frequent of all congenital cardiac malformations (Table I). As a single lesion, it constitutes 7–25 per cent of all such cases. It is often associated with other congenital lesions—patent ductus arteriosus; ventricular septal defect; pulmonary stenosis; common atrioventricular canal (Rokitansky, 1875; Abbott, 1937; Roesler, 1934); transposition of the arterial trunks (Gibson & Clifton, 1938), most often along with ventricular septal defect, with patent ductus arteriosus, or with both (Joules, 1934; Taussig, 1938); with rare venous abnormalities as pulmonary veins emptying into the right auricle (Rokitansky, 1875; Duff, 1938; Ash *et al.*, 1939), or left

superior vena cava (Chase, 1938). It may be complicated by complex lesions, e.g. Fallot's tetralogy (Feldman & Snook, 1938), or by multiple congenital defects (our Case 6). Thus atrial septal defect may accompany almost any congenital lesions, but our paper deals with cases where it was the sole or the predominant congenital lesion.

TABLE I

INCIDENCE OF ATRIAL SEPTAL DEFECT

Author	Consecutive Necropsies	Congenital Heart Disease	Atrial Septal Defect	
			Alone	With other Congenital Heart Lesions
Abbot (1937)	—	1000	72	301
McGinn and White (1936)	7500	67	11	16
Gibson and Clifton (1938)	1950	105	23	12
Ingham (1938)	8314	87	21	—

It is the only congenital lesion that occurs at all commonly with mitral stenosis (Abbott, 1915; Lutembacher, 1916). Anatomical observations on this association have been reported by Louis (1826), Corvisart (1841), Mayne (1848), Peacock (1860), Martineau (1865), Rokitansky (1875), Griffith (1903), and Tylecote (1903). A review of 23 reported cases, with an added case, was published by McGinn and White (1933). Since then, Roesler (1934), Gibson and Roos (1935), Lutembacher (1936), Cossio and Berconsky (1936), Sailer (1936), Van Ruyven (1936), Cossio and Arana (1937), Battro and De La Serna (1937), and Taussig, Harvey, and Follis (1938) have contributed to the subject. Less common are rheumatic affections of the aortic, or of the aortic and mitral (both Jacobius & Moore, 1938), or of all four valves (Taussig *et al.*, 1938). Roesler (1934) believes that three-quarters of the reported cases that he studied had rheumatic valvular disease; among the 20 cases of Rokitansky (1875) 11 had mitral stenosis; and all the 4 cases of Taussig *et al.* (1938), had it. Among 10 cases of our own with necropsy, mitral stenosis was associated in 4 (Cases 7, 8, 9, and 10). There is often adhesive pericarditis as well—the 11 cases of Rokitansky (1875), those reported by Battro and De La Serna (1937), by Cossio and Arana (1937), and by Cossio and Berconsky (1936), and our Case 8.

The frequency of rheumatic heart lesions is in sharp contrast with the rarity of subacute bacterial endocarditis though this is so common with other congenital heart lesions. Roesler (1934) and Taussig *et al.* (1938) even deny its existence; but Griffith (1906) early reported one case with localization on the pulmonary valves, and two appear in the statistics of Abbott (1937). The only one with localization on the septal defect is mentioned by Jacobius and Moore (1938); in our Case 4 the vegetations were in the left auricle but involved neither the defect nor the mitral valve.

The following account is based on a series of 53 cases of atrial septal defect. In 10 the diagnosis was verified by necropsy, and in the rest characteristic clinical and radiological findings seemed to place it beyond reasonable doubt. The age and sex incidence are shown in Table II. We first made this clinical diagnosis in 1933 (Case 3); this patient died in 1935, and the diagnosis was confirmed at necropsy. The remaining cases represent our joint experience up to date, after excluding several doubtful ones.

TABLE II

AGE AND SEX GROUPS IN 53 CASES OF ATRIAL SEPTAL DEFECT (8 WITH MITRAL STENOSIS)

	F.	M.	
0–10 years of age	2	1 =	3 cases
11–20 ,, ,, ,, ...	5	2 =	7 ,,
21–30 ,, ,, ,, ...	9	5 =	14 ,,
31–40 ,, ,, ,, ...	9	1 =	10 ,,
41–50 ,, ,, ,, ...	12	4 =	16 ,,
51–60 ,, ,, ,, ...	3	— =	3 ,,

I. PATHOLOGY

Of the 10 patients with necropsy control, *A.S.D.* was the only lesion in 5: it was associated with mitral stenosis in 4; and with ventricular septal defect, slight patency of the ductus arteriosus, and slight coarctation of the aorta in Case 6.

The age of death was mostly between 30 and 50. The oldest in our series was 46 when she died; the oldest reported, 77 (Tarnower & Woodruff, 1936). The prevalence of females in our necropsy series is even more striking (4:1) than is that of Roesler (1934) (3:2). The cause of death was exceptional in two: subacute bacterial endocarditis in one (Case 4) and paradoxical embolism in the other (Case 7) (see Tables II and III).

TABLE III

CAUSE OF DEATH IN 10 NECROPSY CASES (4 WITH MITRAL STENOSIS

Congestive heart failure	3 cases
Pulmonary infarction	2 ,,
Embolism (one paradoxical)	2 ,,
Subacute bacterial endocarditis	1 case
During operation	1 ,,
Bronchopneumonia	1 ,,

The heart was always greatly enlarged, often huge and square in shape; its weight was 930 g. (Case 9), 540 g. (Case 7) and 540 g. (Case 4). The right cavities composed the anterior surface and the apex of the heart (Figs. 1 and 2A) and the bulk of the organ. The circumference of the right ventricle was 22 cm. and that of the left 12 cm. (Case 8), the proportion between right and left cavities was described as 3:1 (Case 2), and the left ventricle and auricle appeared as an appendix of a huge heart formed by the right cavities and the conus (Case 9). The external aspect of the heart was not very different when mitral stenosis co-existed, but on the whole the heart appeared more voluminous and the disproportion between right and left cavities greater than when it was

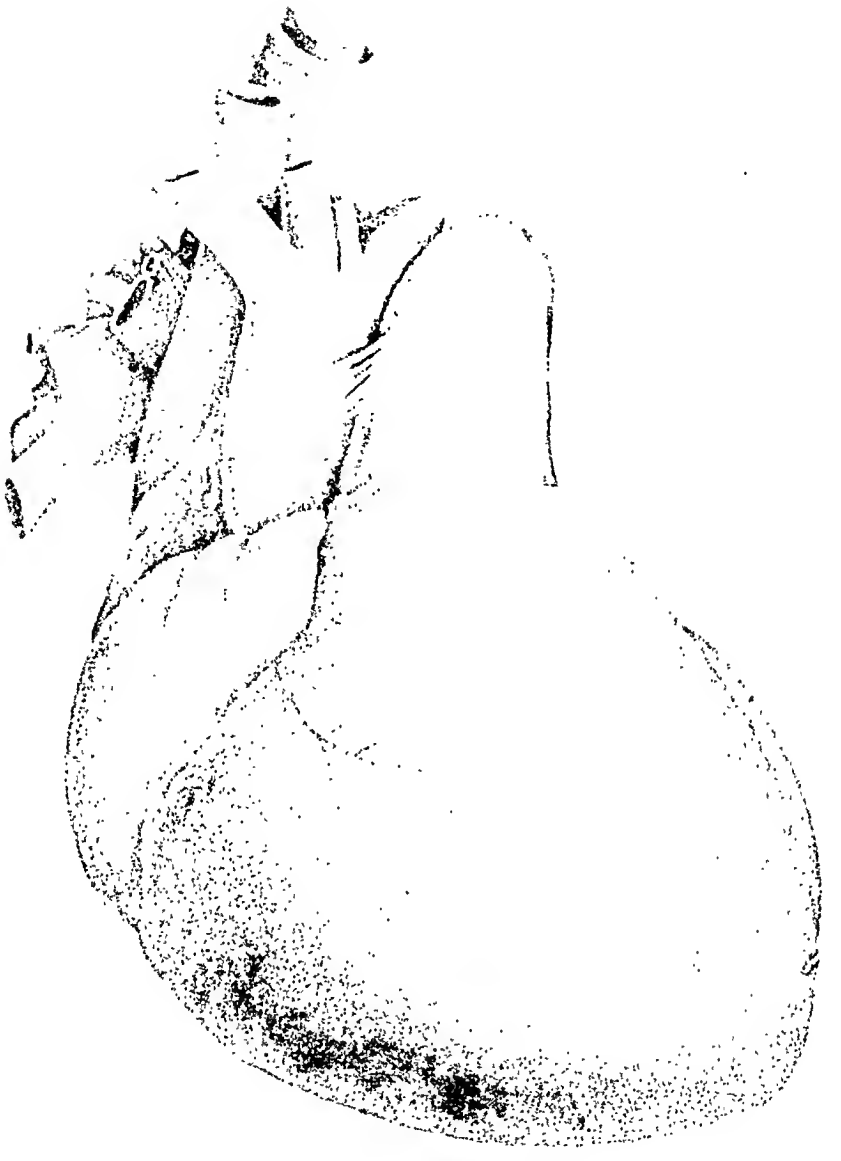

FIG. 1.—Atrial septal defect (*A.S.D.*); Case 3. The anterior surface of the heart, including the apex, is formed by the right chambers and only a small strip of the left ventricle is seen. The pulmonary artery is greatly enlarged; the aorta is normal (cf. Fig. 6).

absent. On the cut surface the right ventricle showed much hypertrophy and dilatation (Figs. 2C and 3). Dilatation was greater with co-existent mitral stenosis and with long-standing failure; hypertrophy with the others. The thickness of the right ventricle was 1·3–1·7 cm. (Case 1) and 1 cm. (Case 4). The left ventricle was of normal thickness (except in Case 6 with ventricular septal defect, where slight hypertrophy was present), but it appeared thicker than the right in Cases 8 and 9 with extreme right ventricular dilatation. Great dilatation of the right auricle was the rule. It was as large as a fist (Case 9), it was three times the size of the left auricle (Case 3), its diameters were 16 cm. by 12 cm. (Case 8), or it contained ante-mortem clots responsible for paradoxical embolism (Case 7). The tricuspid ring, mostly dilated and incompetent, had a circumference of

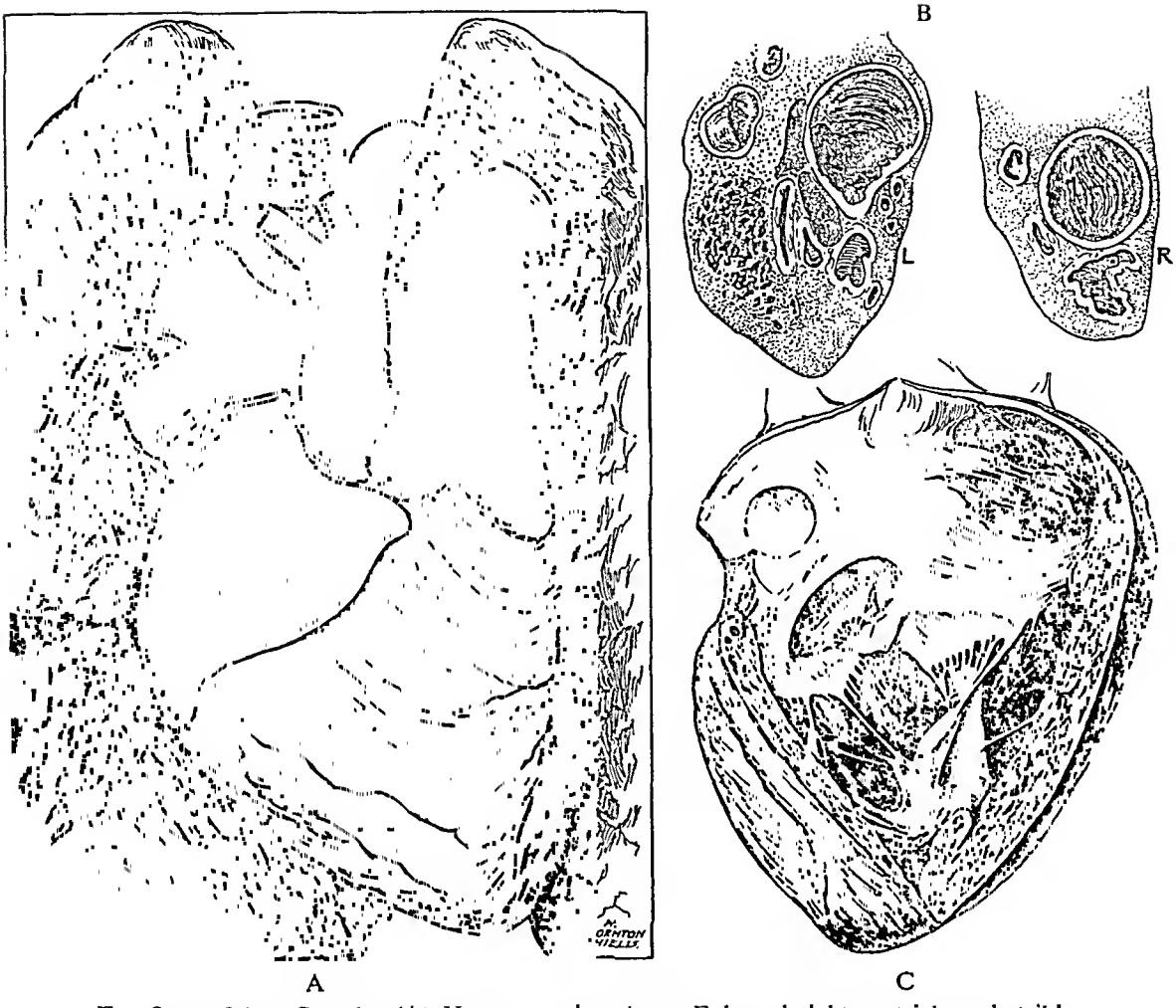

FIG. 2.—*A.S.D.*: Case 1. (A) Heart, anterior view. Enlarged right ventricle and striking disproportion between aorta and pulmonary artery; the branches of the right pulmonary artery are larger than the ascending aorta.

(B) Section of lungs near the hila (left and right); the left and right branches of the pulmonary artery contain recent and old organized clots. The striped light portion within the lumen is old organized clot, the dark portion is recent clot.

(C) Heart opened, showing the dilated right atrium and ventricle. The *A.S.D.* marked (A) occupies the lower part of the septum, just above the tricuspid valve, of which the septal cusp is rudimentary. Normal foramen ovale, patent to probe, lies above it to the left, and the right auricular appendix (auricle) above it to the right (cf. Fig. 9).

16 cm. (Case 8), a diameter of 8·9 cm. (Case 9), or permitted the passage of four fingers (Case 10). The left auricle was normal except in two cases with mitral stenosis and fibrillation, where it was moderately dilated and had a diameter of 9 cm. (Case 8). The mitral stenosis was of buttonhole type in Cases 7, 9, and 10 (Fig. 5); the valve aperture was 2 cm. by 1 cm. in Case 8.

A disproportion comparable with that between the right and left ventricle existed between the pulmonary artery and the aorta. Except once (Case 9) where the pulmonary artery was normal (though the conus was very large) (Fig. 4), the pulmonary artery and its branches were always greatly dilated (Figs. 1 and 2A). The circumference of the pulmonary trunk was 10 cm. (Case 10)

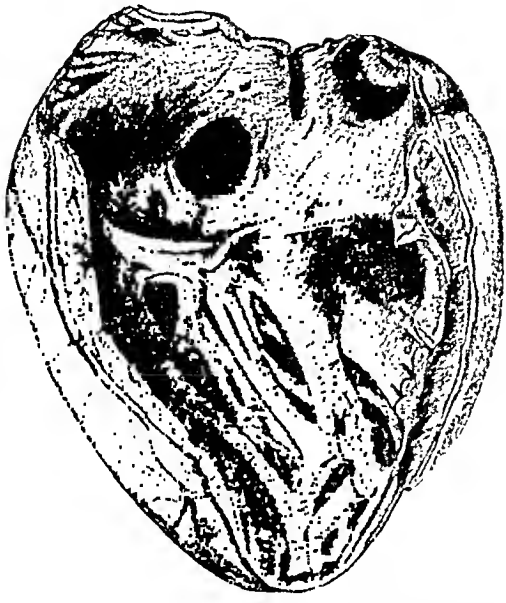

FIG. 3.—*A.S.D.*; Case 2. Heart opened. The right chambers show an oval auricular septal defect at the site of the fossa ovalis. The right atrium is dilated and the right ventricle is dilated and hypertrophied, especially its musculi pectinati.

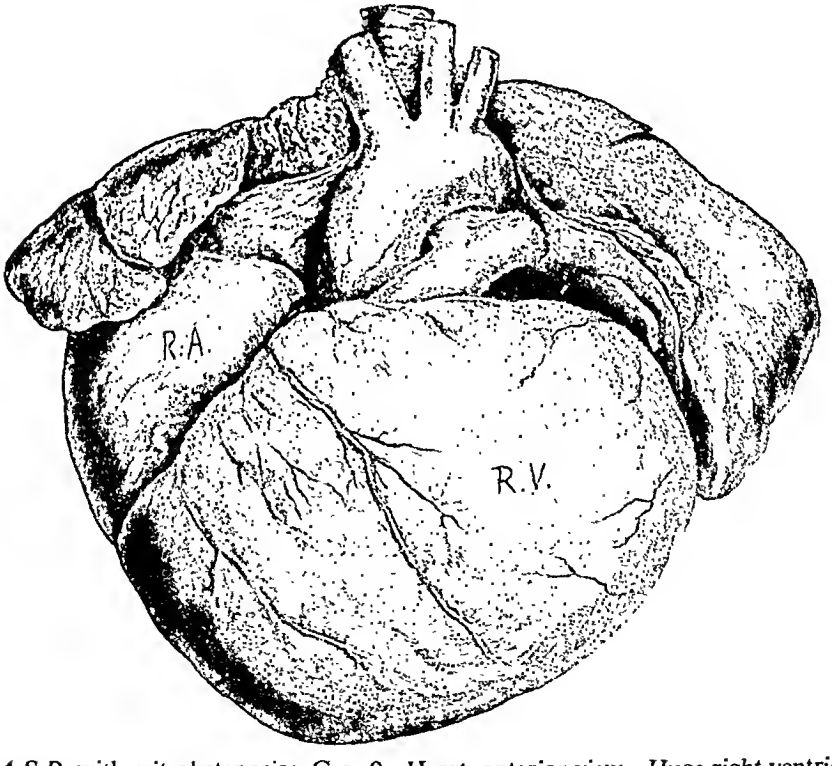

FIG. 4.—*A.S.D.* with mitral stenosis; Case 9. Heart, anterior view. Huge right ventricle and conus, greatly enlarged right auricle. Left ventricle invisible from the front. Pulmonary artery small, aorta normal (cf. Fig. 16).

and 8·5 cm. when that of the aorta was of 5·5 cm. (Case 4). The diameters of the pulmonary artery and aorta at their base were 5·5 and 2·5 cm. (Case 1), 4·5 and 3·0 cm. (Case 3), and 4·5 and 2·3 cm. (Case 10) respectively. The aorta was recorded as small in 7 cases (Cases 1, 2, 5, 6, 7, 9, and 10); and the pulmonary branches, except in Case 9, were larger than the descending aorta (Fig. 2A). The proportion was 3·5 and 2 cm. (Case 3), and 2·7 and 1·3 cm. (Case 10). The right and left pulmonary branches were equal in diameter with the exception of Case 3 where the right was larger than the left (3·5 and 2·7 cm.). The pulmonary artery and its branches were nearly always thickened; severe atheroma was present with extensive old and recent thrombosis in Case 1 (Fig. 2B), and in a lesser degree in Cases 5, 6, and 8. Pulmonary infarction was found in Cases 1, 7, and 8; its part in producing paradoxical embolism in Case 7 seems as obvious as in other reported cases.

The defect in the atrial septum was of oval or circular shape; its diameter was 2·3 by 5 cm. (Case 1), 1·5 cm. (Case 3), 3·5 by 2·5 cm. (Case 4), 5 cm. (Case 5), 3 by 2 cm. (Case 6), 1 by 0·8 cm. (Case 7), 7 by 4 cm. (Case 8), 2 by 3 cm. (Case 9), 5 by 3·5 cm. (Case 10). Multiple defects were found in Case 6, and a strand of fibrous tissue divided the large defect in Case 8. The atrial septum was almost absent in Case 10 (Fig. 5) and only a rudiment

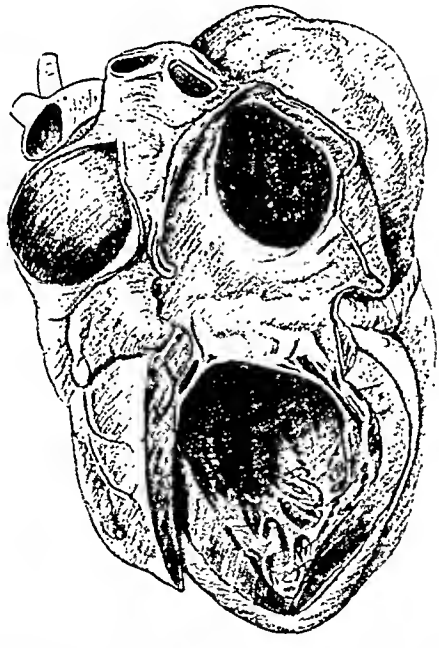

FIG. 5.—*A.S.D.* with mitral stenosis; Case 10. Posterior view of the heart with left ventricle, left auricle, and pulmonary artery opened; almost complete absence of atrial septum The inner surface of the greatly enlarged right auricle is seen through the defect; the pulmonary artery is much dilated; the mitral cusps are fused and thickened.

bordered the aperture at its upper margin. This type of defect is due to an arrest in the early stage of formation of the septum primum (Group 1 of Costa, 1931). The defect in the inferior part of the septum as far as the ventricular septum, associated with an imperfection of the tricuspid valve in Case 1 (Fig. 2C), represents the persistence of the foramen primum due to

an agenesis of the septum intermedium (Group II of Costa, 1931). In all the others the site of the defect was the fossa ovalis, or the upper part of the septum as in Case 2 (Fig. 3). These belong to the commonest group of malformations (Group IV of Costa, 1931) due to agenesis of the septum secundum, which fails to restrict the foramen ovale, and of the septum primum in its latest stage of development, i.e. the formation of the membrane. In other words, there is absence of the valve membrane and the limbus in true *A.S.D.*, at the site of the fossa ovalis. The confusing term of " widely patent foramen ovale " often used for this condition should be reserved for the distension of a functionally patent foramen ovale without congenital septal defect.

The anatomical division of Costa (1931) and that of Routier (1939) into early and late defects has less pathological importance if it is believed that the pathological alterations are related to the size of the defect (Cruveilhier, 1852; Roesler, 1934) and not to its embryological type. Case 7 with the smallest defect in our series (1 cm. by 0·8 cm.) died suddenly at a time when the heart condition had improved with rest and digitalis; and Case 3 with a defect of 1·5 cm. is our oldest necropsy case. But the pathological alterations in these two hearts were quite comparable in degree with those of Cases 5, 8, and 10 with large defects.

II. Clinical Features

Dyspnœa of some degree is the rule though it may be absent. A fair *capacity for exertion*, even with an enlarged heart often on the verge of failure, has been recognized as a sign of a certain importance (Roesler, 1934; Van Ruyven, 1936), since Firket (1890) reported the case of a woman who died when she was 74 after having had 11 pregnancies. Our Case 26 had 5 children; she is now 50 and only recently showed the first signs of failure; Case 32 was a golf champion a few years before when first seen; Case 53 (42 years old), with mitral stenosis, is still an active housewife, and so is Case 20.

Pain. Sternal pain was absent in all but one (Case 3) of our patients. One had left mammary pain, and another had epigastric pain due to the congested liver.

Under-development, small build, or frail constitution was emphasized by Roesler (1934), Leech (1935), Tarnower and Woodruff (1936), Abbott (1937), and Taussig *et al.* (1938); but we think too much has been made of the association though it occurs (Table IV), and also of associated mongolian idiocy and other developmental defects (Abbott, 1937) which are absent in our series.

Cyanosis is an inconstant sign (Laubry & Pezzi, 1921; Pezzi, 1937), and its presence generally implies failure or a greatly enlarged heart about to fail. The type of cyanosis found in *A.S.D.*, first described by Bard and Curtillet (1889) as cyanose tardive, is due to a reversal of the flow left to right *to* right to left, following right ventricular failure. In latent failure the shunt is only on effort and cyanosis is absent during rest. Effort cyanosis, as could be produced in our Cases 2, 11, 18, 22, and 50, is indeed more significant than cyanose tardive which may be no more than the cyanosis of co-existent cardiac failure. The

presence of intense cyanosis with the signs of *A.S.D.* and without failure should suggest a combination with other congenital defects, such as Fallot's tetralogy, common atrioventricular canal, or transposition of the arterial trunks in a child (Case 33), or a complicating thrombosis of the pulmonary branches in an adult (Case 1). Clubbing in our series was infrequent and always linked with cyanosis. The clinical features and cardiac signs are given in Table IV.

TABLE IV

CLINICAL FEATURES

	10 Necropsy Cases	43 Clinical Cases
Good capacity for effort	2	25
Small build (underdeveloped)..	2	6
Cyanosis since birth	1	1
Cyanosis late or on effort	8*	23†
Clubbing	4	8
Præcordial bulge	2	3
Apex-beat forcible (as well as displaced) ..	10	22
Systolic murmur in mitral area	3	24
Mitral stenosis	4	4
Thrill in pulmonary area	2	11
Systolic murmur in pulmonary area	4	28
Diastolic murmur in pulmonary area ..	2	8
Pulmonary second accentuated	4	27
No murmurs	2	6

* All with failure. † 8 with failure.

Cardiac signs.—(1) *Præcordial bulge* is simply a sign of early and pronounced cardiac enlargement, so that its presence (about 10 per cent of our series) is not specific.

(2) The *apex-beat* was both displaced and forcible in more than two thirds of our series. It was displaced to the left in 27 cases, reaching the anterior or middle axillary line in 14 of these, and as low as the sixth space in 8 of these 14. Though this sign commonly indicates left ventricular enlargement, it is here produced by the enlarged *right* ventricle, which pushes the left backwards, and itself enlarges towards the left to form the apex-beat. As Roesler (1934) maintains, the displaced and often forcible apex-beat, so widely accepted as an index of left ventricular enlargement, must be regarded as an important sign of *A.S.D.*, in the absence of aortic valvular disease or hypertension.

(3) *Heart sounds and murmurs.*—There may be no audible physical signs (in 8 of our cases) or such various signs as a systolic murmur in the mitral or pulmonary area or in both. If so, the murmur is usually (but not always) more intense at the pulmonary area where a systolic pulsation or even a thrill may also be felt. The pulmonary second sound is commonly accentuated maybe to reach a metallic character, and it is often palpable. It was followed in 10 of our 53 cases by a soft, blowing, diastolic murmur. The presence of these signs in the pulmonary area in mitral stenosis may suggest a co-existent septal defect though they may be found on rare occasions in advanced mitral stenosis (Graham Steell murmur).

The variety of the auscultatory findings and their absence in typical cases

make it difficult to assign them, as several authors have done (Gibson & Roos, 1935; Leech, 1935; Taussig *et al.*, 1938), to the defect itself. The murmur so produced should be a short presystolic murmur due to contraction of the left auricle, which could hardly be audible on the anterior surface of the heart because its transmission would be hindered by the hypertrophied ventricle (Laubry & Pezzi, 1921). But the systolic thrill and murmur so often audible over the pulmonary area can be readily explained by the dilatation of both conus and pulmonary artery giving rise to a relative stenosis of the lesser distended pulmonary ring (Cossio *et al.*, 1938). Whirling movements of the blood in a dilated pulmonary conus are thought to be responsible for the diastolic murmur in this area by Routier and Heim de Balsac (1938), who reject the possibility of a functional incompetence of the pulmonary valve. We believe that there can be such pulmonary incompetence (Cases 1 and 6). The tricuspid orifice is so often enlarged that it may account for the systolic murmur heard at the apex, here formed by the right ventricle.

III. Radiological Features

Since Assmann (1928) first established the chief radiological sign in atrial septal defect, i.e. the enlargement of the pulmonary artery and of its branches, important contributions have been made to the subject by Dressler and Roesler (1930), Roesler (1934), Battro *et al.* (1937), Cossio and Arana (1937), Levesque *et al.* (1937), Pezzi (1937), Routier *et al.* (1938), Heim de Balsac (1939), Joly (1939), Laubry *et al.* (1939), and Roesler (1939).

Radiological investigation was conducted in 51 of our series, i.e. in all excepting 2 of the 10 necropsy cases who were too ill for this (see Table V).

TABLE V

Radiological Features

	8 Necropsy Cases*	43 Clinical Cases
General enlargement	8	32
Chiefly to the left	7	23
Chiefly to the right	—	5
Equally to left and right	1	8
Aorta small or invisible (anterior view)	6	22
Pulmonary arc very prominent	7	43
Right pulmonary branch enlarged	7	43
Right pulmonary branch pulsatile	6	25 (hilar dance in 5)
Pulmonary artery impression (on œsophagus)	2	16
Left pulmonary branch large (L. oblique)	2	14
Left auricular curve increased (R. oblique)	2 (both in M.S.)	4 (slight in all; 1 M.S.)
Lung field congestion†	1	2 (1 M.S.; 1 failure)
Hydrothorax	2 (one subacute endocarditis, one M.S.; in both terminal only)	—

* Two cases had no X-ray examination.

† Clinical signs of failure were present in all necropsy cases and in 8 of the 43 clinical cases. M.S.=mitral stenosis.

In the anterior position the heart was almost invariably seen to be enlarged. Enlargement to the left was pronounced in 30 cases, and in 6 of them the convexity of the left heart border was displaced as far as the left chest border. Enlargement to the right was pronounced in only 14, and in 6 of them more than to the left. This is opposed to the findings of Battro *et al.* (1937) and Cossio and Arana (1937), who hold that enlargement to the right is a capital sign of *A.S.D.* We think that the right auricle enlarges partly to the front and to the left, contributing to the displacement of the enlarged right ventricle (to the left), because we sometimes found at necropsy gross enlargement of the right auricle without any striking enlargement to the right on their radiographs. The right auricular border may be elongated (Fig. 10), and this, of course, happens more when there is mitral stenosis (Figs. 14 and 16). It is the enlarged right ventricle that determines the convex and prominent left border of the heart and simulates so closely left ventricular enlargement (Fig. 6). The rounded apex seldom merges into the diaphragm but stands out distinct; yet the total appearance is rarely that of a " sabot-shaped " heart, the left border being placed too nearly vertical for this (Figs. 6, 7, 9, and 10), though all our X-ray figures were taken in deep inspiration.

The extreme, almost aneurysmal, bulging of the pulmonary arc gives the heart its typical aspect, and it was the dominant sign in all our cases (Figs. 6, 7, 8, 9, and 10)—except one (Fig. 16); its contour was evenly rounded, and we could not identify any double curve due to combination of the left branch with

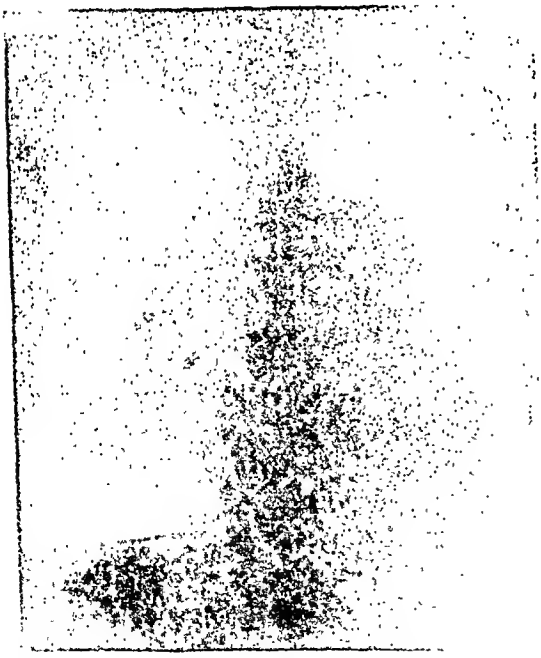

FIG. 6.—*A.S.D.*; Case 3 (necropsy control). Anterior view. Cardiac enlargement with displaced and convex left border due to the right ventricle (see Fig. 1), bulging of the pulmonary artery, enlarged right pulmonary branch. Note absence of lung congestion in this and similar figures. Breast shadows.

FIG. 7.—*A.S.D.*; Case 40. Similar to Fig. 6, but aortic knob visible above dilated pulmonary artery. Great dilatation of right pulmonary branch ("comma shaped"), and a constellation formed by smaller branches.

FIG. 8.—*A.S.D.*; Case 2 (necropsy control). Straight left border, unusual in *A.S.D.*, due to combined dilatation of the pulmonary artery and conus. Simulation of pericardial effusion.

FIG. 9.—*A.S.D.*; Case 1 (necropsy control). Pulmonary arc prominent. Great dilatation and increased density of "comma shaped" right branch of pulmonary artery, which was partially thrombosed (cf. Fig. 2).

FIG. 10.—*A.S.D.*; Case 12. Similar to previous figures, but in addition there is elongation of the right auricular curve.

the main stem as described by Robb and Steinberg (1939), though we think it very possible that the pulmonary arc may be exaggerated by such a combination. The conus of the right ventricle was scarcely prominent, and a straight left border—comparable with that of mitral stenosis—was only seen once (Fig. 8). The main pulmonary branches were always enlarged. In the anterior position the right branch formed a large, dense, defined and often comma-shaped shadow (Figs. 7 and 9). It contrasted with the clear lung fields, especially as pulmonary congestion and hydrothorax were almost always lacking even with congestive failure (see Table V). The pulmonary artery often pulsated visibly, particularly its right branch, producing the "hilar dance" described by Pezzi (1925, 1932) as a radiological sign of pulmonary incompetence. Yet we saw it in cases without pulmonary incompetence, and sometimes failed to see it when pulmonary incompetence was noted (pulmonary diastolic murmur). Such great pulsation is not always seen, though occasionally a lack of pulsation with increased density implies local thrombosis (Fig. 9).

The aortic knob was small or wanting (anterior view) in 28 of the 51 cases, and was normal in the others.

In the right (I) oblique position, the enlarged pulmonary artery with the conus increases the width of the heart shadow in its upper third and forms a squarish mass that bulges both to the front and to the back (Fig. 11). An oval, pulsating, denser shadow can often be discerned within it, in front of the aorta and just above the right bronchus; it is the "pulmonal fleck" (Schwedel & Epstein, 1936) and corresponds to the bifurcation and the right branch of the pulmonary artery seen in cross section. The straightness of the posterior border in its lower (left auricular) position, is a characteristic of the picture, and barium in the œsophagus will emphasize it. The aortic impression on the œsophagus is usually small and sometimes it is absent. In contrast, below it may be a large, deep impression—an exaggerated pulmonary artery impression (Parkinson & Bedford, 1931). The course of the œsophagus in the left auricular region is straight or slightly curved, quite unlike that featuring mitral stenosis (Figs. 12 and 15). There were, however, 6 cases in which this left auricular curve was more pronounced though never extreme. In 2 of them, necropsy showed mitral stenosis and some enlargement of the left auricle; of the other 4, one had also mitral stenosis clinically, but the remainder had no signs of it. It is admitted that general cardiac enlargement itself may accentuate in some degree the left auricular curve (Babey, 1937).

The left (II) oblique position is the only one in which the left branch of the pulmonary artery, hidden in the anterior position behind the greatly dilated pulmonary trunk, can be seen in its course (Schwedel & Epstein, 1936; Laubry *et al.*, 1939). In 16 of our series it obscured the aortic window by appearing under the aortic arch as a large denser shadow (Fig. 13). The prominence of the right ventricle on the sternal border of the heart is another typical feature in this view.

Radiokymographic studies in *A.S.D.* (Battro *et al.*, 1937; Levesque *et al.*, 1937; Laubry *et al.*, 1939) have shown normal ventricular pulsation on the left border with ventricular pulsation in its lower part (Battro *et al.*, 1937), an

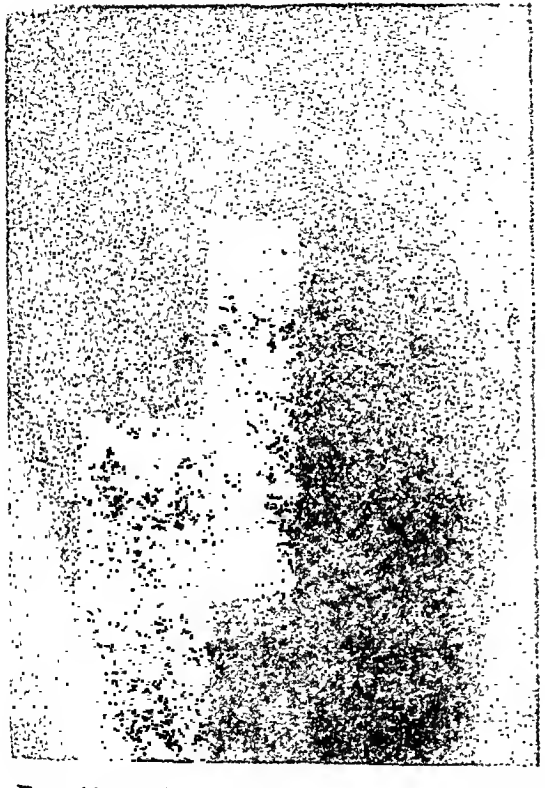

FIG. 11.—*A.S.D.*; Case 3 (necropsy control). Right (I) oblique view. The greatly dilated pulmonary artery and its division give a squarish appearance. The lower part of the posterior heart border is straight (no enlargement of left auricle).

FIG. 12.—*A.S.D.*; Case 48. Right (I) oblique view with barium in the œsophagus. There are two impressions in the upper half of the œsophagus; an upper small one due to the aorta, and a lower large one due to the pulmonary artery. The left auricular curve is normal.

FIG. 13.—*A.S.D.*; Case 3 (necropsy control). Left (II) oblique view. The base of the light aortic triangle is formed by the summit of the aorta. Below that is seen the large, denser left branch of the pulmonary artery, running transversely and obscuring the aortic window. Note the increased convexity of the right ventricle.

arterial curve in the upper pulmonary artery region, and an arterial curve at the right hilum.

With associated mitral stenosis there is likely to be extreme enlargement of the right auricle, both to X-rays and at necropsy, and this is well shown in Figs. 4, 14, and 16.

In rare cases the pulmonary artery and its branches are not enlarged so that the radiological aspect is quite different (as in Case 9). In the anterior position (Fig. 16) the heart is enormously enlarged to left and right, and of spherical shape suggesting pericardial effusion. The pulmonary artery is not visible though the conus is prominent. The greatly displaced right border crosses the diaphragm at an obtuse angle. In the right (I) oblique position the left auricle is not particularly prominent. The anatomical peculiarity of this heart with *A.S.D.* and mitral stenosis (Case 9) was the huge conus almost like a third ventricle (Fig. 4). A transition between this and the typical radiological appearance is to be found in the cases of Roesler (1934) and of Joly (1939), where there was a certain degree of pulmonary artery enlargement but the branches were hidden behind the huge heart. Joly (1939) calls such hearts " pear-shaped " (pyriform), and believes that they occur only in men, and stresses their association with a small aorta; yet in our Case 9 the aorta was normal at necropsy, and Roesler (1934) found this form in a woman.

IV. Electrocardiographic Features

Atrial septal defect is the only congenital heart lesion in which auricular fibrillation is likely to occur. Among 300 cases of congenital heart diseases Brumlik (1937) found fibrillation only once, and this was in *A.S.D.* The reason for the association may be gathered from Table VI: in our series it was present in 6 patients (Fig. 17); five of them had mitral stenosis and the sixth, with *A.S.D.* only, was aged 58 and our oldest patient. If not mitral stenosis implying rheumatism, the predisposing factor for fibrillation appears to be increasing age. We have not found any reports of fibrillation in pure *A.S.D.* under 50 years of age, and in all the younger cases reported it was associated with mitral stenosis. In Case 10 there was alternating fibrillation and flutter, and in Cases 12 and 44 (both pure *A.S.D.* cases) there were paroxysmal attacks of nodal tachycardia. Complete heart block has been by Taussig *et al.* (1938).

Large and high P waves in one or more leads, described as characteristic for *A.S.D.* by Leech (1935), were found in 15 records (Figs. 19A; 20A, C). A large bifid P was seen three times, without mitral stenosis (Fig. 19B). A long P–R interval is rarely mentioned in congenital heart disease, but it has been noticed and ascribed to a secondary myocardial lesion (Mannheimer, 1939), or to a ventricular septal defect (Brumlik, 1937) when there is bundle branch block. In *A.S.D.* it has not hitherto been remarked though it is apparent in some published records (Cesari, 1935; Brown, 1939). The P–R interval was 0·20 second or more in 19 of our series (Figs. 19A, 20A); it was longest (0·28 sec.) in Case 27 who had also partial right bundle branch block with an enlarged

FIG. 14.—*A.S.D.* with mitral stenosis; Case 51. Anterior view; similar to *A.S.D.*, but with greater prominence and lengthening of the right auricular border. Incidental scoliosis.

FIG. 15.—Same case as Fig. 14. Right (I) oblique view, barium in the œsophagus; long pulmonary artery impression but *no* enlargement of the left auricle (*A.S.D.* with mitral stenosis).

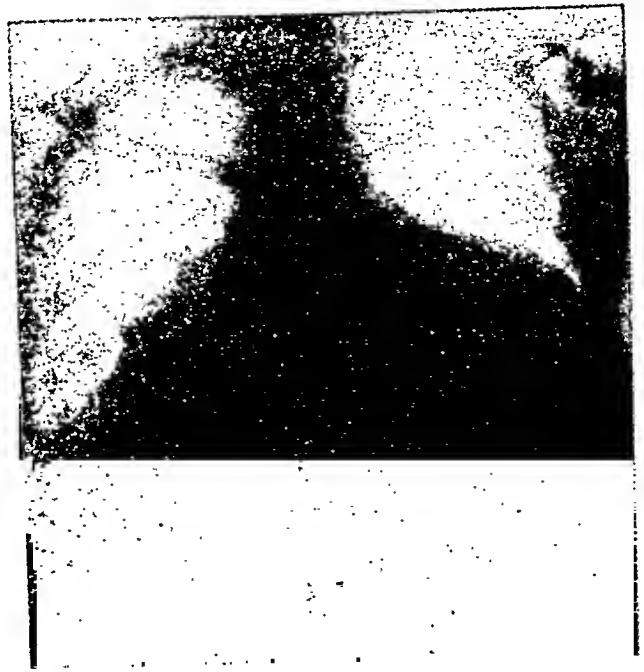

FIG. 16.—*A.S.D.* with mitral stenosis; rare variety; Case 9 (necropsy control). Huge, globular heart simulating pericardial effusion. The convex left heart border reaches the left chest wall, the right auricle is greatly displaced and elongated, but the pulmonary artery region is not prominent (cf. Fig. 4).

heart but no signs of failure. In Case 28 (Fig. 18) a second record, taken four years after the first and in failure, showed an increase from 0·18 to 0·26 sec.

TABLE VI

ELECTROCARDIOGRAPHIC FEATURES

	10 Necropsy Cases	43 Clinical Cases
Normal rhythm	6	41
Auricular fibrillation	4 (all M.S.*)	2 (1 M.S.)
Auricular fibrillation and flutter	1 (M.S.)	—
Right axis deviation with or without wide QRS	8	33
Left axis deviation	—	2 (1 sl.)
No axis deviation	2	8
Large or bifid P	3	12
P–R 0·20 second or over	3	16
QRS over 0·10 second	3	23
Right bundle branch block	1 (M.S.)	4 (2 M.S.)
T_1 inversion	—	2
T_1, T_2, T_3 inversion	—	1
T_2, T_3 inversion	3	17
Paroxysmal nodal tachycardia	—	2
Auricular extrasystoles	—	1

* M.S.=mitral stenosis.

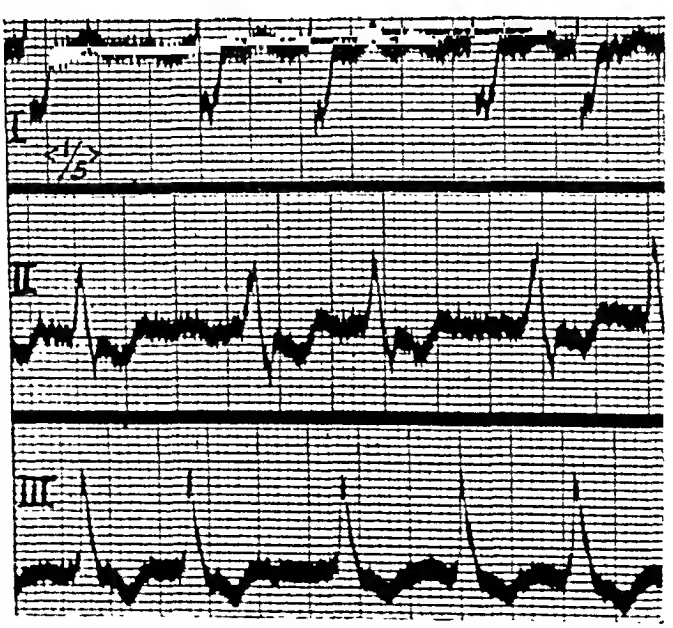

FIG. 17.—*A.S.D.* with mitral stenosis; Case 51. Auricular fibrillation and right bundle branch block (traditional type).

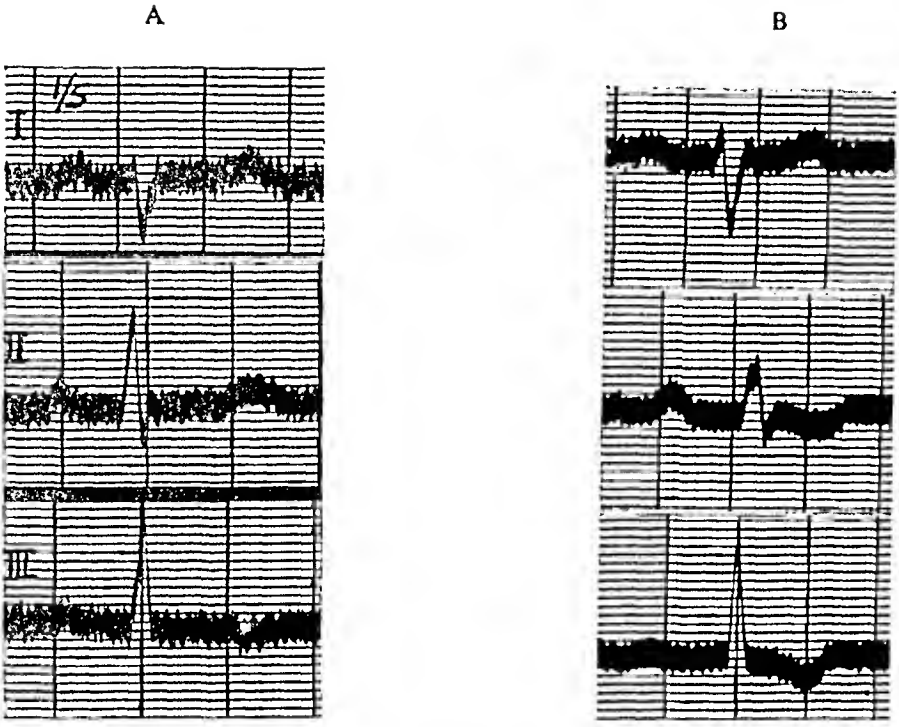

FIG. 18.—*A.S.D.*; Case 28.

(A) Right axis deviation.

(B) Record taken four years after (A) shows prolonged P–R interval (0·27 sec.), notched and widened QRS_2 (0·10 sec.) and inversion of T_2 and T_3.

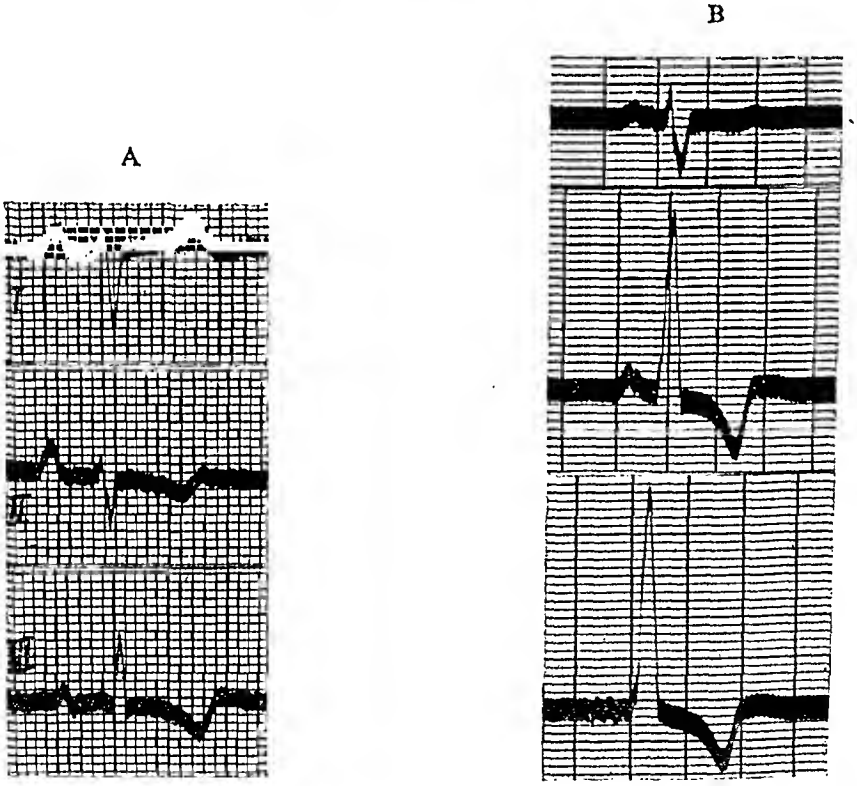

FIG. 19.—*A.S.D.* with right axis deviation.

(A) Case 1 (necropsy control). Large P_2, prolonged P–R interval (0·22 sec.), inversion of T_2 and T_3.

(B) Case 12. High voltage curve, bifid P_2 and P_3, sharp inversion of T_2 and T_3.

The main direction of the waves was (notably in leads I and III) that of right axis deviation, in four fifths of our cases if we include right axis deviation itself and partial right bundle branch block whether of the traditional or of the newer type. It was of high degree (high voltage) in about half of them (Fig. 19B), and of medium or low degree in the other half. The voltage was low in the

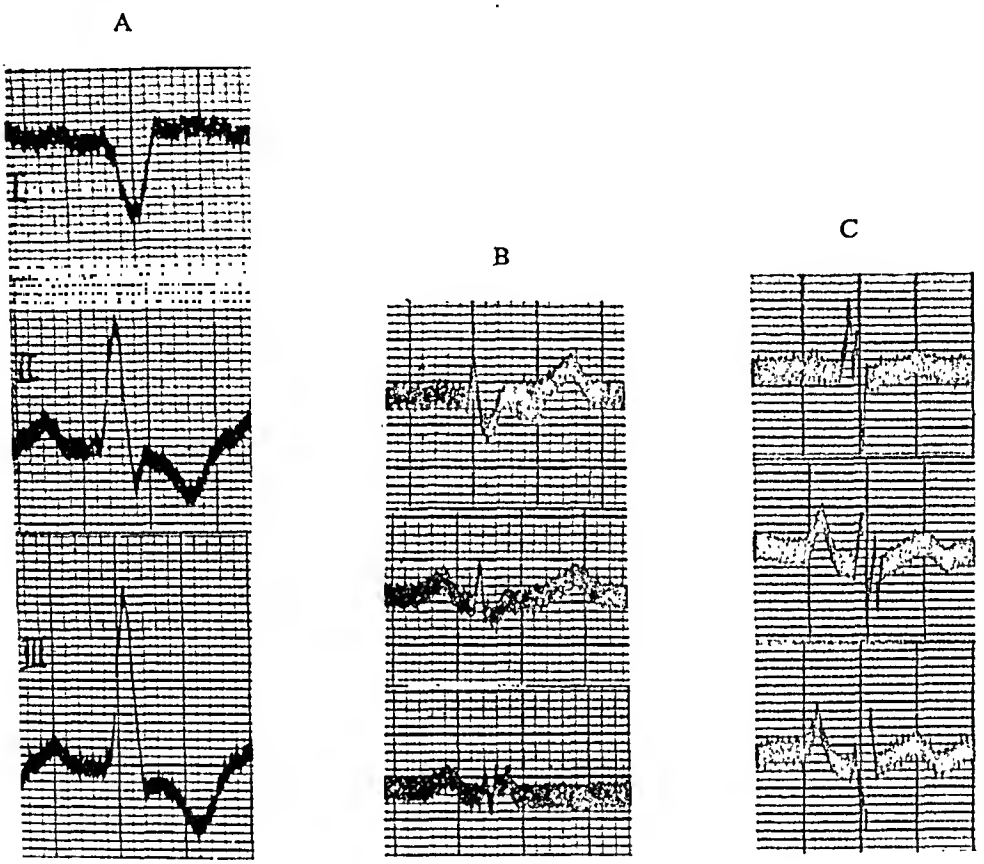

FIG. 20.—*A.S.D.* with bundle branch block.

(A) Case 5 (necropsy control). P–R interval of 0·22 sec., large P_2, right bundle branch block of the traditional type.
(B) Case 17. Right bundle branch block of the newer type.
(C) Case 30. Large P_2 and P_3. Bizarre, notched and widened (0·12 sec.) ventricular complexes.

cases with severe failure (Cases 4, 7, 8, and 9), but it was also low in Cases 17 and 21 with large hearts in the absence of failure.

A widened ventricular complex sometimes suggesting right bundle block was described in *A.S.D.* (Bedford & Brown, 1937; Routier & de Balsac, 1938), and its diagnostic importance was stressed by Routier *et al.* (1940, *b*). It was present in 26 of our series. Every transition from a prolonged intraventricular conduction or simple notching to right bundle branch block, sometimes of the old (Fig. 20A), sometimes of the newer type (Fig. 20B) could be found; incomplete bundle block was more frequent (21 cases) than complete (5 cases). This wide and notched QRS was found only twice below the age of 30 and then with moderate cardiac enlargement. This fact with its appearance in the later

record of Case 28 (Fig. 18B) also indicates, as Routier *et al.* (1940) maintain, the progressive effect of the lesion on the myocardium accompanied by enlargement: the bundle block appearance is not part of the congenital lesion but a sequel of it. It was nearly always accompanied by an inversion of the T wave in lead II or III, or in both, though in nine cases such inversion of T was present with normal ventricular complexes (Fig. 19A). It is related to right ventricular stress (Barnes & Whitten, 1929; Brumlik, 1937) and is another feature of the second record in Fig. 18B.

V. Cardiac Enlargement and Failure

The onset of failure was never before the third decade of life, except in Cases 2 and 4 where it appeared at 7 and 28 years and was due to complicating broncho-pneumonia and bacterial endocarditis respectively. In our clinical series, failure appeared in two between 30 and 40, and in four between 50 and 60.

The failure is typically right-sided. After a period of dyspnœa on exertion for 10–20 years, often surprisingly slight, the liver enlarges and sometimes pulsates from tricuspid incompetence. Cyanosis begins to appear on slight effort. This stage may last for a few years before œdema and ascites supervene.

Pulmonary congestion and hydrothorax are rare, as always in pure right-sided failure (see Radiological Features), and are referable to associated auricular fibrillation rather than to the defect itself (Cases 7, 8, 9, 34, and 51). Pulmonary infarction may be a terminal event; but if pulmonary infarction occurs early, it depends upon pulmonary arteriosclerosis, as it did in cases 37 and 42, both with hæmoptysis at the age of 22 and 26, and in the two necropsy Cases 1 and 5.

The mechanism of right-sided heart failure in atrial septal defect is explained by the pressure difference in the two atria. The higher pressure in the left atrium which normally causes the closure of the foramen ovale is responsible for the shunt from left to right. The increased blood volume passing through the right cavities and the pulmonary arteries is the cause of their enlargement, and conversely of the smallness of the aorta and the left ventricle. When after decades of adaptation to the increased circulatory load the right ventricle fails, the raised pressure in the right auricle gives rise to the known signs of right ventricular failure and reverses the flow and produces cyanosis (cyanose tardive). It would be logical to suppose that the precocity of failure should depend upon the blood volume passing through the defect, according to the dimension of the defect and to the degree of left auricular pressure. But it is difficult to establish a strict relation between the dimension of the defect and the size of the heart chambers (see under Pathology); on the other hand, the increased left auricular pressure from co-existent mitral stenosis produced the greatest distension of the heart chambers.

This view of the circulatory mechanism admitted since Mayne (1848), Rokitansky (1875), and Griffith (1906), has recently been rejected by Laubry and Lenégre (1939), Laubry *et al.* (1939), Marchal *et al.* (1939), Routier (1939), and Routier and Brumlik (1940). The French authors regard *A.S.D.* as a silent symptomless lesion, a minor element in a complex congenital heart lesion

characterized by huge right cavities and a dilated pulmonary artery, and a hypoplasic aorta and left ventricle. The *A.S.D.* itself would not account for the secondary alterations leading to failure, unless it were associated with mitral stenosis. But the cases of Laubry and Lenégre (1939) and of Marchal *et al.* (1939)—regarded as supporting their opinion—are admittedly examples of widely patent foramen ovale (not true *A.S.D.*), and this explains the absence of typical heart responses. Nor are the three cases of chronic pulmonary disease published by Routier and Brumlik (1940) convincing, for it is well known that fibroid lung may produce dilatation of the pulmonary artery and a heart very like that found in *A.S.D.* Another argument advanced by Joly (1939) and Olmer *et al.* (1939) is based on the variety of the heart changes (if any) in *A.S.D.*, sometimes enlargement of the pulmonary artery, but in other cases enlargement of the conus, or even a normal heart. But as shown in our series, enlargement of the pulmonary artery is almost a constant feature in real *A.S.D.*, as it was in all the series yet published (Rokitansky, 1875; Roesler, 1934; McGinn & White, 1933). This would not exclude the possibility that the conus may enlarge more than the pulmonary artery as in Roesler's case (1934), or that in exceptional cases a huge conus and a normal pulmonary artery may be found (our Case 9). Even in simple mitral stenosis, it is sometimes the conus and sometimes the pulmonary artery that enlarges the more. The different behaviour of the pulmonary artery in these circumstances is not only referable to the mechanical effect created by the lesion, but to a congenital hypoplasia of the vessel wall which is fairly common (Clarke, Coombs, Hadfield, & Todd, 1929; Costa, 1929; Brenner, 1935). In the second case of Olmer *et al.* (1939), in which *A.S.D.* was found in a woman aged 27 who died of intercurrent disease with a heart that was otherwise normal at necropsy, no measurements of the defect are given and the accompanying figure suggests that it was very small.

Against these later views are many facts to show it is the *A.S.D.* that produces the pathological alterations and eventually the heart failure:

(1) Since *A.S.D.* gives somewhat similar anatomical alterations whether alone or combined with mitral stenosis, the complicating mitral stenosis cannot be the only and sufficient cause of such alterations.

(2) A normal aorta with a large pulmonary artery, found in 4 of our 10 necropsies, is against a congenital inequality of the two vessels. The hypoplasia of the aorta in the 6 remaining necropsy cases is ascribed to the diminished blood volume reaching the left ventricle: a similar aortic hypoplasia is seen when mitral stenosis develops in early life. An unequal division of the bulbus arteriosus, as described by Assmann (1928) and Oppenheimer (1933), and as applied by the French authors, does occasionally produce a pathological and radiological picture similar to that of *A.S.D.* (see Differential Diagnosis).

(3) Freedom from symptoms and good capacity for exertion up to the twenties or thirties indicates late and progressive enlargement resulting from the *A.S.D.*

(4) That dilatation of the right ventricle is a sequential progression and not part of the congenital lesion is suggested by the changes in the electrocardiogram already described.

VI. Diagnosis

The diagnosis of atrial septal defect rests mainly on its radiological features. The great, even aneurysmal, dilatation of the pulmonary artery with its grossly dilated and often pulsating right branch, standing out against a clear lung field, strikes the eye definitively in the anterior view. The heart is enlarged as a whole and especially to the left. The enlarged pulmonary artery is well seen in the right (I) oblique view, but the visualized œsophagus shows no particular enlargement of the left auricle.

The *clinical signs* are of limited value and are essentially those of enlargement of the right ventricle and dilatation of the pulmonary artery without obvious cause. Thus the apex beat is forcible and displaced to the *left*, but the blood pressure is normal or low. The signs of dilatation of the pulmonary artery may be unobtrusive, or may be those of aneurysm such as palpable pulsation, systolic thrill, and diastolic shock. A systolic murmur (sometimes also a diastolic) and an accentuated second sound are usually heard at the pulmonary area. Cyanosis from birth is exceptional, and it is absent or slight unless terminal heart failure is present; clubbing is uncommon. Widespread pulmonary congestion is noticeably absent, and there is greater capacity for exertion than would be expected from the clinical and even more from the radiological pointers.

The *electrocardiogram* may help, for right axis deviation with normal rhythm is the rule, with QRS often notched and widened and approximating to the right bundle block type, yet with T inverted independently in leads II and III. Large P waves and a prolonged P–R interval are not infrequent.

A.S.D. associated with mitral stenosis produces a very similar combination of signs, but in addition there is the auscultatory monomark of mitral stenosis, and auricular fibrillation is common. The left auricle is not enlarged; or if it is, then not disproportionately to the general enlargement. Great prominence of the right auricle is of major importance in the diagnosis of this combination. In brief, the radiological aspects of *A.S.D.* with or without mitral stenosis are similar, though the former may perhaps show more enlargement to the right (R.A.) and the clinical and electrocardiographic findings of mitral stenosis.

Differential diagnosis is concerned with any heart condition, acquired or congenital, in which great enlargement of the pulmonary artery and its branches is found. This applies to mitral stenosis, patent ductus arteriosus, pulmonary or conus stenosis with normal ventricular septum, ventricular septal defect alone or with dextroposed aorta (Eisenmenger's disease), pulmonary heart disease, pulmonary artery disease, and primary dilatation of the pulmonary artery with right ventricular hypertrophy (pulmonary hypertension). In attempting differential diagnosis it should always be remembered that *A.S.D.* is often combined with other congenital lesions.

(*a*) Mitral stenosis. Fair capacity for exertion in mitral stenosis with an enlarged heart is unusual, and, of course, auricular fibrillation is common. By X-rays, the heart presents a straight left border because the conus as well as the pulmonary artery are both projecting. The left auricle invariably enlarges and displaces the barium-filled œsophagus in the right oblique view. The lung

fields are clouded and merge with the hila because there is general pulmonary congestion. Difficulties can arise if in mitral stenosis there is an exceptionally large pulmonary artery—perhaps with relative pulmonary incompetence (Graham Steell)—but then the enlarged left auricle and the diffuse pulmonary congestion will exclude *A.S.D.*, whether with or without mitral stenosis.

(*b*) Patent ductus arteriosus. Only when the typical murmur is absent and the pulmonary artery and branches are unusually large will confusion arise. Cyanosis is absent in both lesions and a pulmonary diastolic murmur is occasionally heard in both. A normal or almost normal electrocardiogram favours patent ductus arteriosus (Drawe *et al.*, 1937) and the cardiac enlargement is expected to be slighter than in *A.S.D.*

(*c*) In both pulmonary or conus (right ventricle) stenosis with a normal ventricular septum the pulmonary second sound is absent and the branches of the pulmonary artery are not enlarged though the stem of the pulmonary artery may be distended.

(*d*) In isolated ventricular septal defect (Roger's disease), gross enlargement of the pulmonary artery is most exceptional, and in Eisenmenger's disease the dextroposition of the aorta may be distinctive.

(*e*) In pulmonary heart disease the enlargement of the pulmonary artery (and the conus) seldom reaches the degree so common in *A.S.D.*, and the causal emphysema, chronic bronchitis, or fibroid lung is obvious from the history and the signs.

(*f*) Pulmonary artery disease is far from common; it may be a primary atheroma or more likely syphilis of the trunk and main branches. There is also the obliterative endarteritis of the finer branches alone or as part of a chronic lung disease. The diagnosis can be very difficult, yet the long history of pulmonary symptoms and the cyanosis or the positive Wassermann reaction may decide it.

(*g*) Most difficult of all to distinguish from *A.S.D.* are the cases of *primary dilatation of the pulmonary artery* and its branches, without much pathological alteration excepting right ventricular hypertrophy. This group has been attributed to unequal division of the common trunk (Assmann, 1928), idiopathic dilatation of the pulmonary artery (Oppenheimer, 1933), congenital disproportion between aorta and pulmonary artery (Routier & Brumlik, 1940), pulmonary hypertension (Lian, 1940; East, 1940; Armstrong, 1940), and to idiopathic right ventricular hypertrophy (De Navasquez, Forbes, & Holling, 1940). Lian (1940) published 21 clinical cases that he believed were of this nature, but they were a mixed group and no necropsy evidence is afforded; in fact necropsies on this condition are rarely though increasingly reported. (Oppenheimer, 2 cases; East, 3 cases; De Navasquez *et al.*, 3 cases). It must be admitted that the whole picture in advanced cases is identical and differential diagnosis during life may be impossible. But *A.S.D.* is so common and "pulmonary hypertension" so rare, that pathological statistics (probability) should weight in any doubtful case of gross enlargement of the pulmonary artery and its branches.

SUMMARY

(1) A patent foramen ovale (patent to probe or even to pencil), found in 20–30 per cent of all necropsies, is an anatomical variation of a normal condition; it is clinically silent except that when distended by increased right auricular pressure (" widely patent ") it can give rise to terminal cyanosis and paradoxical embolism. In contrast, atrial septal defect (*A.S.D.*) is a real congenital malformation due to a defective union or malformation of the three embryonic septa forming the definitive atrial septum. It occurs (*a*) as a single lesion and constitutes 7–25 per cent of all congenital heart lesions; (*b*) as an associated lesion with any other congenital heart lesion; (*c*) combined with mitral stenosis, and then probably with auricular fibrillation.

(2) A diagnosis of *A.S.D.* was made in 53 patients, 10 with necropsy control and 43 without. An association with mitral stenosis was present in 4 of the necropsy cases—one had also adhesive pericarditis—and in 4 of the clinical cases, and with patent ductus arteriosus and ventricular septum defect in 1 necropsy case. The lesion may be found at any age and the prevalence of females was striking (4:1). The age of death was mostly between 30 and 50. The cause of death was congestive heart failure in three, pulmonary infarction in two, embolism (one paradoxical) in two, subacute bacterial endocarditis in one, broncho-pneumonia in one, and operation in one.

(3) The pathological findings in the 10 necropsy cases were:

(*a*) A large heart consisting mainly of right ventricle, conus, and right auricle, with a disproportion between right and left cavities of about 3:1 in bulk, or even more in cases of associated mitral stenosis.

(*b*) Gross dilatation of the pulmonary artery and its branches, except in one case where there was a big conus with a normal pulmonary artery. Severe arteriosclerosis (with thrombosis of the pulmonary artery and branches) was found only once, and in lesser degree three times; the remainder showed simple thickening only.

(*c*) The atrial septum was almost absent in one; the defect involved the lower part of the septum and there was an imperfect formation of the tricuspid valve (persistent ostium primum) in another; and its site was the enlarged fossa ovalis or the upper part of the septum in the remainder. The dimension of the defect varied from 1 by 0·8 cm. to 7 by 4 cm. There was no strict relation between the dimension of the defect and the degree of pathological adjustment.

(4) Auditory signs in *A.S.D.* are lacking, for the lesion itself produces no murmur. Any murmurs heard are due to dilatation of the right ventricle and the conus, and relative stenosis of the less distensible pulmonary ring. A systolic murmur in the pulmonary area was found in 32 and was accompanied by a systolic thrill in 13 cases. An accentuated pulmonary second sound in 31, was followed by a diastolic murmur in 10: no murmurs were recorded in 8 cases. A forcible and displaced apex-beat without other cause and due to the large right ventricle proved to be a most suggestive sign (32 cases). Common clinical features in our 53 cases were fair capacity for exertion even with an enlarged heart and signs of failure (27 cases), slight cyanosis on effort or late cyanosis

(31 cases). Underdevelopment, though occasionally seen (8 cases), was far less frequent than in other published statistics.

(5) The radiological features in 51 cases indicated its paramount importance in diagnosis. General enlargement was present in 40, chiefly to the left in 30. The prominence of the left border proved to be due, however, to the enlarged right ventricle (see left oblique view) which displaced the left ventricle backwards. Great projection of the right auricle points to coexisting mitral stenosis. The bulging of the pulmonary stem and conus with the enlarged, dense right hilum shadow (right branch of the pulmonary artery) gives the heart its striking appearance in the anterior view. Excessive pulsation of the hilum was noticed in 31 instances; but a real " hilar dance " could be seen in only 5, and then there was not always pulmonary incompetence. Lack of pulsation with increased density was diagnostic of local thrombosis in one necropsy case. The aorta was small or invisible in about half the cases. In the right (I) oblique view the enlargement of the pulmonary stem and conus became even more evident, and a pulmonary impression on the œsophagus was observed in 18 of our cases. In the left (II) oblique view, the enlarged left pulmonary branch obscured the aortic window and the right ventricle was unduly convex. Negative radiological signs of importance were the absence of the left auricular curve in the right oblique view, and the absence of lung congestion. In the six cases where the left auricular curve was prominent it was proportionate to the general cardiac enlargement. Pulmonary congestion was found in only three cases having severe failure, and hydrothorax in only two—both in terminal conditions.

(6) The electrocardiogram often helped in diagnosis. Normal rhythm was the rule (in 47), and when auricular fibrillation was present it was not due to the lesion itself but either to rheumatism (mitral stenosis) or to age changes. Right axis deviation was very frequent (in 41), if we include partial right bundle branch block (26); complete right bundle branch block of the older or newer type was found in 5. T_2 and T_3 were inverted, independently of the bundle branch block character of the ventricular complex (in 9). A prolonged P–R interval of 0·20 second or over, and large or bifid P waves were not infrequent.

(7) Failure appeared usually between the ages of 30 and 50, and was typically right ventricular. Late cyanosis and liver enlargement were its main features; dyspnœa was moderate and pulmonary congestion was rare unless in the terminal stage when œdema and ascites might supervene. Pulmonary infarction early in the course was rare and then based upon pulmonary arteriosclerosis. Subacute bacterial endocarditis as a complication was exceptional (one necropsy case). The mechanism of failure is explained by the increased blood volume that the right ventricle has to propel, for the left atrium with its higher pressure partly diverts through the defect blood from the left cavities. We cannot accept the hypothesis recently advanced by French authors that the disproportion between right and left cavities and between pulmonary artery and aorta respectively is due to a congenital malformation unless *A.S.D.* is associated with mitral stenosis. The similarity of the pathological findings in *A.S.D.* with or without mitral stenosis, the progressive dilatation of the right ventricle, and the often normal aorta make us reject this view.

(8) Differential diagnosis is concerned with all congenital or acquired heart conditions in which there is a dilatation of the pulmonary artery and its branches, and these are enumerated. Pulmonary artery disease and primary dilatation of the pulmonary artery with right ventricular hypertrophy, so-called pulmonary hypertension, can produce a similar radiological and pathological picture. But these are exceptional conditions, while atrial septal defect is a far more likely cause of gross dilatation of the pulmonary artery and its branches.

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REFERENCES

Abbott, M. E. (1915). *Bull. Internat. Assoc. Med. Mus.*, **5**, 129.
—— (1937). *Congenital Heart Disease in Nelson's New Loose Leaf Medicine*, 18th ed., vol. IV, 207.
Armstrong, T. G. (1940). *Brit. Heart J.*, **2**, 201.
Ash, R., Wolman, I., and Bromer, R. (1939). *Amer. J. Dis. Child.*, **58**, 8.
Assmann, H. (1928). *Die klinische Röntgendiagnostik der inneren Erkrankungen*, 4th ed., Leipzig.
Babey, A. (1937). *Amer. Heart J.*, **13**, 228.
Bard, L., and Curtillet, J. (1889). *Rev. Médecine*, **9**, 993.
Barnard, W. G. (1930). *Quart. J. Med.*, **23**, 305.
Barnes, A. R., and Whitten, M. B. (1929). *Amer. Heart J.*, **5**, 14.
Battro, A., and De La Serna, A. (1937). *Rev. argent. Cardiol.*, **3**, 427.
Bedford, D. E., and Brown, J. W. (1937). *Brit. Encycl. Med. Pract.*, vol. VI.
Brenner, O. (1935). *Arch. intern. Med.*, **56**, 211.
Brown, J. W. (1939). *Congenital Heart Disease*, London.
Brumlik, J. (1937). *Ann. Soc. Tchécosl. Cardiol.*, **5**, 109.
Cesari, A. M. (1935). *Cuore e Circolaz.*, **19**, 213.
Chase, R. E. (1938). *J. Techn. Methods*, **18**, 90.
Clarke, R. C., Coombs, C. F., Hadfield, G., and Todd, A. T. (1929). *Quart. J. Med.*, **21**, 51.
Corvisart (1841). *Traité des maladies du cœur*, vol. II, 680, Paris.
Cossio, P., and Arana, R. S. (1937). *Bull. Acad. Med. Paris*, **117**, 212.
——, Arana, R. S., Berconsky, I., and Kreutzer, R. (1938). *Sem. méd., B. Aires*, **2**,, 364.
——, and Berconsky, I. (1936). *Rev. argent. Cardiol.*, **3**, 360.
Costa, A. (1928). *Arch. Patol. clin. Med.*, **7**, 329.
—— (1931). *Cuore e Circolaz.*, **15**, 263.
Cruveilhier, J. (1852). *Traité d'anatomie pathologique générale*, vol. II, Paris.
De Navasquez, S., Forbes, J. R., and Holling, H. E. (1940). *Brit. Heart J.*, **2**, 177.
Drawe, C. E., Hafkesbring, E. M., and Ashman, R. (1937). *Amer. J. Dis. Child.*, **53**, 1470.
Dressler, W., and Roesler, H. (1930). *Z. klin. Med.*, **112**, 421.
Duff, P. A. (1938). *J. Techn. Methods*, **18**, 106.
East, T. (1940). *Brit. Heart J.*, **2**, 189.
Feldman, W. M., and Snook, S. G. (1938). *Brit. J. Child. Dis.*, **35**, 183.
Firket, C. (1880). *Ann. Soc. méd. chir. Liége*, 19, 188 (quoted by Roesler, 1934).
Gibson, S., and Clifton, W. M. (1938). *Amer. J. Dis. Child.*, **55**, 761.
——, and Roos, A. (1935). *Ibid.*, **50**, 1465.
Griffith, T. W. (1903). *Med. Chronicle, Manchester.*, **37**, 385.
—— (1906). *Lancet*, **2**, 973.
Heim de Balsac, R. (1939). *Arch. Mal. Cœur*, **32**, 199.
Hirschboeck, F. J. (1935). *Amer. J. med. Sci.*, **189**, 236.
Ingham, D. W. (1938). *J. Techn. Methods*, **18**, 131.
Jacobius, H. L., and Moore, R. A. (1938). *J. Techn. Methods*, **18**, 133.
Joly, F. (1939). *Paris méd.*, **1**, 441.
—— (1939). *Arch. Mal. Cœur*, **32**, 611.
Jones, R. (1936). *Brit. med. J.*, **2**, 225.
Joules, H. (1934). *Lancet*, **2**, 1338
Koritschoner, R. (1936). *J. Amer. med. Ass.*, **106**, 1269.
Laubry, C., Cottenot, P., Routier, D., and Heim de Balsac, R. (1939). *Radiologie Clinique du cœur et des gros vaisseaux, Paris.*
Laubry, C., and Lenègre, J. (1939). *Arch. Mal. Cœur*, **32**, 197.

Laubry, C., and Pezzi, C. (1921). *Traité des maladies congénitales du cœur, Paris.*
Leech, C. B. (1935). *J. Pediat.*, **7**, 802.
Levesque, J., Heim de Balsac, R., and Guichard, H. (1937). *Ann. de Méd.*, **42**, 229.
Lian, C. (1940). *Arch. Mal. Cœur*, **33**, 67.
Löfgren, L. (1937). *Finska Läksällsk. Handl.*, 80, 919.
Louis, P. C. A. (1826). *Mémoires ou recherches anatomo-pathologiques, Paris.*
Lutembacher, R. (1916). *Arch. Mal. Cœur*, **9**, 237.
—— (1936). *Ibid.*, **29**, 229.
Mannheimer, E. (1939). *Acta pædiatr. Stockh.*, **24**, 128.
Marchal, J., Ortholan, J., and Breton, P. (1939). *Arch. Mal. Cœur*, **32**, 189.
Martineau (1865). *Bull. Soc. Anat. Paris*, **10**, 310.
Mayne, A. B. (1848). *Dublin Quart. J. Med. Sci.*, **5**, 46.
McGinn, S., and White, P. D. (1933). *Amer. Heart J.*, **9**, 1.
—— (1936). *New Engl. J. Med.*, **214**, 763.
McLeod, N. (1936). *J. Techn. Methods*, **15**, 131.
O'Farrell, P. T. (1938). *Irish J. Med. Sci.*, **6**, 597.
Olmer, D., Jouve, A., and Claustre, P. (1939). *Marseille méd.*, **1**, 487.
Oppenheimer, B. S. (1933). *Trans. Assoc. Amer. Phys.*, **48**, 290.
Parkinson, J., and Bedford, D. E. (1931). *Lancet*, **2**, 337.
Peacock, T. B. (1860). *Trans. Path. Soc. London*, **11**, 68.
Pezzi, C. (1925). *Atti Soc. Lomb. Sci. Med. biol.*, **14**, 52.
—— (1932). *Contributions to Medical Sciences in Honor of Dr. E. Libman.* International Press, New York, **3**, 931.
—— (1937). *Sur le diagnostic de la communication interauriculaire* (Prof. Libensky's Jubilee Book, p. 52, Prague).
Robb, G. P., and Steinberg, I. (1939). *Amer. J. Roentgen.*, **41**, 1; **42**, 14.
Roesler, H. (1934). *Arch. intern. Med.*, **54**, 339.
—— (1937). *Clinical Roentgenology of the Cardiovascular System*, London.
—— (1939). *Atlas of Cardioroentgenology*, Springfield, Ill., U.S.A.
Rokitansky, C. (1875). *Die Defecte der Scheidewände des Herzens*, Wien.
Routier, D. (1939). *Arch. Mal. Cœur*, **32**, 207.
—— and Heim de Balsac, R. (1938). *Bull. Soc. Belge Cardiol.*, **5**, 41.
—— and Brumlik, J. (1940, *a*). *Arch. Mal. Cœur*, **33**, 184.
——, Brumlik, J., and Malinsky, A. (1940, *b*). *Ibid.*, 33, 40.
Sailer, S. (1936). *Amer. J. Path.*, **12**, 259.
Schwedel, J. B., and Epstein, B. S. (1936). *Amer. Heart J.*, **11**, 292.
Tarnower, H., and Woodruff, I. O. (1936). *Ibid.*, **12**, 358.
Taussig, H. B. (1938). *Ibid.*, **16**, 728.
—— Harvey, A. McG., and Follis, R. H. (1938). *Bull. Johns Hopkins Hosp.*, **63**, 61.
Thompson, T., and Evans, W. (1930). *Quart. J. Med.*, **23**, 135.
Tylecote, F. E. (1903). *Lancet*, **2**, 821.
Van Ruyven, R. L. J. (1936). *Bull. Soc. Belg. Card.*, **3**, 98.

APPENDIX OF CASE NOTES

The following abbreviations have been used:

A.B.	=	apex beat.	R.V. or L.V.	}	right or left ventricle.
B.P.	=	blood pressure.			
P.A.	=	pulmonary artery.			
R.A. or L.A.	}	right or left auricle.	W.R.	=	Wassermann reaction.
			a.a.l.	=	anterior axillary line.
			l.o.p.	=	left oblique position.
R.A.D.	=	right axis deviation.	r.o.p.	=	right oblique position.

Case 1.—H. H., male, aged 44.

History.—Served in Navy 1910–1919, always fit; worked as driver until 1933. Never blue as a child; blueness first noticed about 1919, later worse and associated with dyspnœa on effort. Occasional hæmoptysis, accompanied by severe pain in right side of chest in 1929 and 1937.

Examination (January 1938).—Intense cyanosis, with clubbing; great dyspnœa. Pulse 80, regular. B.P. 110/85. Heart; A.B. fifth left space, a.a.l. Expansile and forcible pulsation in second and third left space near sternum with diastolic shock. Pulmonary second sound very loud, followed by a low pitched diastolic murmur along left sternal border to apex (murmur heard by D.E.B. in 1933 and interpreted as

pulmonary incompetence). Lungs: crepitations at both bases. Liver: slightly enlarged. Blood count: red cells, 6·5 m.; hæm. 140 per cent. Circulatory time (decholin) varied from 15 to 20 sec.

Radioscopy.—Heart moderately enlarged to left. Aneurysmal dilatation of pulmonary arc and right P.A. with scarcely any visible pulsation (Fig. 9). Deep P.A. impression on œsophagus, L.A. normal (r.o.p., barium in œsophagus). R.V. prominent, intensely pulsating (l.o.p.).

Electrocardiogram (Fig. 19A).—Normal rhythm; R.A.D.; P–R prolonged (0·22 sec.); large P_2; T_2 and T_3 inverted.

Course.—Worked until May, 1938, as lift attendant, when sudden severe pain in left side of chest, and cough with pink frothy expectoration. Re-admitted as acute pulmonary œdema; signs of consolidation in left lower lobe. Died four days later. The clinical diagnosis was auricular septum defect with pulmonary incompetence and aneurysmal dilatation of pulmonary artery and branches with old and terminal pulmonary thrombosis.

Necropsy (May, 1938).—On opening the pericardium, P.A. enormously dilated; diameter of trunk 5·5 cm.; that of the aorta, 2·5 cm. at base. Most of left heart contour formed by R.V. The right and left branches of the P.A. greatly dilated (3·5 cm. in diameter), and walls hardened and thickened. Right and left pulmonary branches largely filled with laminated and organized also recent clots; two-thirds of the lumen of the right branch, half the lumen of the left branch obliterated (Fig. 2).

On opening the heart, R.V. much dilated and hypertrophied, its wall being 1·3 to 1·7 cm. thick. The septal cusp of the tricuspid valve imperfect and rudimentary. R.A. dilated.

Foramen ovale closed, but admits a probe. Fossa ovalis, 2 cm. in diameter, bulges into L.A. Below (1·5 cm.) the lower border of the fossa ovalis is an oval aperture of 2 by 3·5 cm. The upper border of this aperture is formed by a double fold of the septum, the lower border being formed by the tricuspid and mitral valves.

Considerable atheroma and patchy calcification of P.A. and main branches. Pulmonary cusps normal, but valve incompetent from dilatation of artery. L.V., L.A., mitral and aortic valves are normal.

Final Diagnosis.—Defect of interauricular septum (lower part), hypertrophy and dilatation of R.V., aneurysmal dilatation of P.A. and main branches with organized thrombus of branches. Terminal bronchopneumonia.

Case 2.—H. J., female, aged 7 years.

History.—Attacks of cyanosis and dyspnœa on exercise. Lately troubled with cough, fever, and sweating.

Examination.—Cyanosis and dyspnœa on the slightest exertion. Wasting and weakness. Heart; A.B. visible in sixth left space, a.a.l.; forcible. Palpable thrill over whole præcordial area. Loud rumbling murmur throughout the whole cardiac cycle, maximum sixth space beyond nipple line, but heard over entire chest. Lungs: crepitations and rhonchi, general signs of consolidation over left chest. Liver enlarged.

Radioscopy (Fig. 8). Greatly enlarged heart joining in its lower half the left chest wall. Pulmonary arc and conus very prominent, right pulmonary branch enlarged. Aortic knob invisible.

Electrocardiogram.—Rate 125, normal rhythm; R.A.D.

Course.—Died a week after admission. The clinical diagnosis was pericarditis and congenital heart disease.

Necropsy.—Pericardium contains small amount of clear fluid. Heart enlarged to left chest wall. R.A. and R.V. form two thirds of heart volume. Large patent foramen ovale (Fig. 3). P.A. three times normal size. Small aorta. Œdema and congestion of lungs. Bronchopneumonia. Liver congested.

Case 3.—N. K., female, aged 44. Married, 3 children.

History.—Growing pains, but not acute rheumatism or chorea. At 39 told she had valvular heart disease; then no complaints. Two years sternal pain across upper part of chest towards both axillæ, at any time and sometimes lasting hours. During such attacks, sense of suffocation and temporary loss of voice.

Examination (June 1933).—Rather nervous, breathless woman. Thyroid gland not enlarged. Slight if any cyanosis; no clubbing. Pulse 90–100, regular. B.P.

125/85. Heart; A.B. sixth left space, a.a.l.; forcible. Sounds, I and II all areas. Doubtful diastolic murmur at apex. Pulmonary second sound heard. Lungs, normal. Liver enlarged; no œdema. W.R. negative.

Radioscopy.—Heart moderately enlarged as a whole; left border displaced more than right. Pulmonary arc very large and prominent, excessive pulsation. Right P.A. very large; moderate pulsation. L.A. not enlarged (r.o.p.; barium in œsophagus). Aortic knob small, scarcely visible (Figs. 6, 11, and 13).

Electrocardiogram.—Normal rhythm; R.A.D. with high voltage. P–R prolonged (0·22 sec.); T_1 upright, T_2 and T_3 inverted.

Course.—Slowly progressive cardiac failure during 1934–35. Orthopnœa, swelling of liver, œdema. Cyanosis only during the last months of life.

Necropsy (April 1935); heart only examined. On opening chest, heart greatly enlarged to right and left; anterior surface formed by R.V. and R.A. P.A. and conus much enlarged; P.A. 4·5 cm. across at its base, the aorta 3 cm. (Fig. 1).

On opening heart, R.V. enormously dilated and its walls hypertrophied, dilatation involving the main cavity and the conus. Tricuspid orifice widened and incompetent. R.A. enlarged and about three times the size of L.A.

In the upper part of the atrial septum above the fossa ovalis, is a circular aperture, 1·5 cm. in diameter. The pulmonary trunk is enormously dilated and its wall thickened, and so are the two main branches. The right P.A. is 3·5 cm. in diameter, the left 2·7 cm. The aorta is of small calibre and measures (beyond the left subclavian) 2 cm. in diameter.

Case 4.—K. O., female, aged 28. Married, no children.

History.—No acute rheumatism or chorea. Always said to have a " weak heart "; easily short of breath, and unable to play games. For three months, cough with irregular pyrexia. Admitted to hospital.

Examination (July 1936).—No cyanosis or clubbing. Dyspnœa; œdema of lower limbs. Pulse 110, regular. B.P. 120/70. Heart; A.B. sixth left space, a.a.l. Cardiac pulsation to right of sternum. No thrill. Systolic murmur over mitral area becoming loud and rough over pulmonary area. Second sound scarcely audible. Lungs, crepitations both bases. Liver, slightly enlarged; ascites. Spleen easily felt.

Radioscopy.—Heart moderately enlarged as a whole. Pulmonary arc and conus prominent, pulmonary branches enlarged and intensely pulsating. R.A. very prominent, left cardiac border displaced. Lungs congested.

Electrocardiogram.—Normal rhythm; low voltage curve; R.A.D.

Course.—Continued irregular pyrexia up to 101°. No petechiæ, no clubbing. Repeated blood cultures always sterile. Progressive diminution of hæmoglobin and red cells. Albumin and blood in the urine. Blood urea reached 154, congestive heart failure progressively increased, serous effusions developed, and patient died in October 1936.

Necropsy.—Heart weight 540 g. Great dilatation and conspicuous hypertrophy of R.V., 1 cm. thick; normal L.V. P.A. dilated and thickened, circumference of pulmonary ring 8·5 cm., of aortic ring 5·5 cm. In L.A., extensive confluent vegetations, just contiguous but not involving mitral valve, extending far up its wall. Large interauricular septal defect at the site of the foramen ovale, measuring 3·5 by 2·5 cm. Great dilatation of R.A. and of the tricuspid ring. Kidneys very small, bright-red spots on surface; cortex mottled on section. Spleen enlarged, two small infarcts. Œdema of lungs; effusion in serous cavities; anasarca.

Final Diagnosis.—Subacute bacterial endocarditis. Atrial septal defect.

Case 5.—E. P., female, aged 35. Married, one child.

History.—No acute rheumatism. After childbirth, aged 26, first medically examined and was told she had a " bad heart." No cyanosis in childhood. Six years, effort dyspnœa; two years cyanosis, palpitation and increasing dyspnœa.

Examination (September 1936).—Obvious cyanosis, no clubbing. Pulse 100, regular. B.P. 100/75. Heart; A.B. in mid-axillary line. No murmurs. Pulmonary second sound accentuated and duplicated. Palpable systolic impulse without thrill over pulmonary area. No signs of failure.

Radioscopy.—Heart greatly enlarged, left border reaches left chest wall: sabot-shaped. R.A. prominent. Aneurysmal dilatation of pulmonary arc. Right branch of pulmonary artery enlarged, unduly pulsating. Small aorta.

Electrocardiogram.—Normal rhythm; R.A.D. with high voltage. P–R full (0·2 sec.); large P waves in leads II and III; QRS 0·12 sec.; T_2 and T_3 sharply inverted.

Course.—Sudden pain developed in left chest, worse on deep breathing. Rigor. Deep cyanosis, severe dyspnœa, pleural friction at left base. Pulmonary infarction was diagnosed, condition became worse, and she died October 1936.

Necropsy.—Heart greatly enlarged and in contact with left chest wall. Whole anterior surface formed by R.A. and R.V. with its conus. L.V. invisible from the front. R.A. dilated and hypertrophied. L.A. only slightly dilated. L.V. of normal size. P.A. huge and its branches greatly dilated and contain ante-mortem clots. Thrombus in bifurcation of left pulmonary branch. Pulmonary infarcts in left upper and right lower lobes. Large circular defect in auricular septum measuring 5 cm.; no other congenital lesion.

Case 6*.—L. T., female, aged 37. Single.

History.—Congenital heart lesion recognized since early childhood. Lifelong dyspnœa and cyanosis. Increasing dyspnœa, with œdema of legs for three months.

Examination.—Cyanosis and orthopnœa; some clubbing. Neck veins distended. Pulse regular. B.P. 130/110. Heart; præcordial bulge. A.B., fifth left space, mid-axillary line. Systolic and diastolic thrill with expansile pulsation, at second and third left spaces near sternum. Systolic murmur in mitral area; loud pulmonary systolic murmur, accentuated second sound, and rough diastolic murmur at third left space close to the sternum. Lungs, basal crepitations. Liver, enlarged. W.R. negative.

Radioscopy.—Greatly enlarged heart; left border displaced, R.A. prominent. Aneurysmal dilatation of pulmonary arc. Right branch enlarged and pulsatile. L.A. normal (r.o.p., barium in œsophagus).

Electrocardiogram.—Normal rhythm, R.A.D., ventricular extrasystoles.

Course.—Improvement with rest and digitalis. Four weeks later, sudden death from cerebral embolism.

Necropsy.—Heart greatly enlarged, chiefly R.V. and R.A. Aneurysmal dilatation of P.A., enlargement of its main branches, thickening of the wall, slight atheroma. Pulmonary orifice dilated, incompetent. Right P.A. larger than descending aorta. Relatively small aorta; beyond left subclavian aortic narrowing just admitting finger tip. Ductus arteriosus patent at aortic end, and of conical configuration with a narrow slit at its pulmonary end. The atrial septum contains three apertures, one large and two small. The large is oval, 3 cm. by 2 cm., situated at the upper and posterior part of the septum, just in front of the superior vena cava orifice. The two smaller apertures are below the larger one. The interventricular septum is imperfect at its base having a 2 cm. wide defect opening into the right ventricle just below tricuspid valve, and into the L.V. immediately below the aortic orifice. Aorta communicates with both ventricles. Tricuspid orifice dilated, cusps thickened, calcified deposit between two cusps. L.A. normal. L.V. slightly enlarged and hypertrophied. R.V. much hypertrophied and dilated.

Final Diagnosis.—Defect of atrial septum (persistent ostium secundum); aneurysmal dilatation of pulmonary artery with incompetence of pulmonary valves; defect of ventricular septum; great enlargement of right heart chambers; minimal patency of ductus arteriosus; slight coaretation of aorta.

Case 7.—D. E., female, aged 43. Married, no children.

History.—As a child rheumatic fever; aged 12 and 16, chorea. Aged 27, in hospital with mitral stenosis and heart failure, and again aged 39 when heart was fibrillating. Aged 41, cerebral embolism. The day of admission, sudden severe pain and cramp in left leg.

Examination (June 1937).—Severe dyspnœa. Jugular veins distended. Goitre, tremor, sweating, slight exophthalmos. Pulse; apical rate 180, auricular fibrillation. B.P. 160/100. Left leg and foot pale and cold; no arterial pulsation. Heart; A.B. in a.a.l. Systolic thrill at pulmonary area. Systolic shock over P.A. and conus. Rumbling diastolic murmur at apex. Liver, enlarged.

* The pathological specimen of Case 6, which is in the Heart Hospital Museum, was presented to us by Dr. H. Joules (Joules, 1934) with typical radiographs, and he has kindly approved our redescribing it.

Radioscopy.—Moderate general enlargement of the heart particularly to left. Prominent pulmonary arc, large right P.A. Aortic knob invisible. Moderate prominence of L.A. (r.o.p., barium in œsophagus). R.V. prominent, aortic window closed by enlarged left P.A. (left oblique).

Electrocardiogram.—Auricular fibrillation. Slight R.A.D.; T_3 inverted.

Course.—Improved with rest and digitalis.

August, 1937.—Sudden severe pain in right arm. Tenderness over axillary artery, no pulse felt. Right arm cold from shoulder, hand and forearm powerless, all sensation lost. Heart condition then became worse, with lung congestion and sacral œdema. Because of the persisting pain and danger of gangrene, amputation attempted, but she died during operation.

Necropsy (August 1937).—Heart weight 570 g.; moderately enlarged as a whole. Pulmonary trunk and main intrapulmonary branches much dilated and their walls thickened. R.V. hypertrophied and dilated. R.A. moderately dilated, contains ante-mortem clot adherent to the wall. In the upper part of the foramen ovale there is an oval aperture of about 1 cm. by 0·8 cm. Mitral valve thickened, producing button-hole slit admitting tip of index finger. L.A. moderately enlarged. Aortic, pulmonary and tricuspid valves normal. Infarct at the base of the lower lobe of the left lung with ante-mortem thrombus blocking one main division of the pulmonary branch.

Case 8.—H. F., female, aged 45.

History.—No acute rheumatism. Twenty years, shortness of breath on exertion. Four years, swelling of abdomen and ankles. Eighteen months ago pneumonia, worse since then.

Examination (October 1937).—Severe orthopnœa. Cyanosis, clubbing. Gross œdema of lower limbs. Pulse; apical rate 110, auricular fibrillation. B.P. 110/70. Heart; A.B. fifth left space, 1 in. beyond mid-clavicular line. Systolic thrill and harsh systolic murmur at mitral area. Pulmonary second accentuated. Lungs, crepitations both bases. Liver, enlarged.

Radioscopy.—Patient too ill for this.

Electrocardiogram.—Auricular fibrillation. Low voltage; QRS slurred and notched in all leads.

Course.—Slowly progressive cardiac failure with venous congestion and anasarca. Died January 1938.

Necropsy.—Foramen ovale widely patent (7 by 4 cm.). Fenestrated flap of fibrous tissue (4 by 2 cm. and 0·05 cm. thick) arising from posterior margin of foramen and continued as a strand of fibrous tissue (0·1 cm. thick) to centre of anterior margin of foramen. Conspicuous fibrotic thickening, slight shortening and partial fusion of cusps of mitral valve; stenosis (2 by 1 cm.) of mitral orifice; fibrous thickening, shortening and focal fusion of chordæ tendineæ of mitral, excepting those of left side of anterior cusp. Slight fibrous thickening without shortening of inferior half of anterior cusp of tricuspid; dilatation of tricuspid ring (16 cm. circumf.). Considerable dilatation but no hypertrophy of almost spherical L.A. (about 9 cm. diam.); slight opaque white thickening of endocardium. Slight dilatation (12 cm. circumf.), no gross hypertrophy, but slight hypertrophy of muscle fibres of L.V. Great dilatation (up to 22 cm. circumf.), gross hypertrophy (up to 0·6 cm. thick) and hypertropthy of muscle fibres of R.V. Focal fibrosis of myocardium of both ventricles and slight fibrotic thickening of pericardium. Great dilatation (anterior surface 16 cm. long, 12 cm. across), no gross hypertrophy, but great hypertrophy of scanty muscle fibres of R.A.; severe fibrosis of myocardium; slight opaque white elastic hyperplasia of endocardium, fibrous and elastic thickening of pericardium. Clear yellow pericardial effusion (3 oz.). Great dilatation of P.A. (10 cm. circumf. just above valves) and of all its branches within lungs (up to 4·6 cm. circumf.). A few fatty flecks of atheroma in hypertrophied intima of P.A. Less dilatation of branches of pulmonary veins. Slightly purulent mucous exudate in trachea and bronchi. Congestion, slight induration, slight intra-alveolar hæmorrhage and hæmosiderosis and slight œdema of lungs. Collapse of lower anterior half and lower posterior angle of left lower lobe. Considerable bronchopneumonia in left lower lobe. Clear yellow pleural effusions (16 oz. right, 4 oz. left). Clear yellow peritoneal effusion (3 oz.). Pitting œdema of feet, legs, thighs, and lumbar region.

Final Diagnosis.—Bronchopneumonia. Chronic heart failure. Mitral stenosis. Chronic rheumatic endocarditis. Atrial septal defect at site of fossa ovalis. (Lutembacher's syndrome.)

Case 9.—E. G., male, aged 33.

History.—No acute rheumatism or chorea. Blue since birth. Attended school, but played no games. Light work since leaving school. Frequent epistaxis; otherwise well until aged 23, when twice admitted to hospital for dyspnœa. Hæmoptysis few days before second admission.

Examination (November 1936).—Undersized; kyphosis. Deep cyanosis with clubbing. Pulse, 100, auricular fibrillation. B.P. 105/95. Heart; bulging of the chest wall to left of sternum. A.B., sixth left space, a.a.l. Rumbling diastolic murmur at apex. Harsh systolic murmur at pulmonary area. Lungs; bilateral basal crepitations. Liver; enlarged, pulsating. Blood count; hæmoglobin 160 per cent, red cells 6·9 million.

Radioscopy.—Huge heart extending to left chest wall. Enlargement and hypertrophy of R.V., R.A., and L.A. P.A. invisible. Small aorta. Right hilus hidden behind dilated R.A. (Fig. 16).

Electrocardiogram.—Auricular fibrillation. Right bundle branch block.

Course.—Admission to hospital in 1937, 1938, and 1939, for progressively increasing heart failure with deep cyanosis, orthopnœa, large pulsating liver, and general œdema. Died November 1939.

Necropsy.—Huge heart, weight 930 g. Enormous R.V. and conus forming a large square-shaped sac. R.A. also grossly enlarged. Aorta small. P.A. normal. L.V. invisible from front (Fig. 4).

On opening the heart the R.V. forms an enormous cavity separated from the huge conus by a very thick muscular band. Wall of R.V. little if at all thickened. Tricuspid orifice dilated (8 to 9 cm. in diameter). R.A. very large, cavity takes whole fist.

In the atrial septum in the position of the foramen ovale is a large, obliquely-placed aperture, 2 by 3 cm. in diameter and admitting the tips of two fingers. Left auricular cavity little if at all enlarged. Mitral valve rigid, calcarcous, cusps fused and stenosed, orifice admits the tip of one finger. L.V. normal; its wall much thicker than that of the R.V.

Case 10.—R. S., female, aged 33. Married, two children.

History.—Alleged rheumatism 7 years ago, not previously. Admitted to hospital as "cardiac failure, amenorrhœa (? pregnancy)."

Examination (January 1938).—High colour, but no cyanosis. Pulse 130, regular, small volume. Œdema of ankles. Heart; A.B., sixth left space, greatly enlarged. Systolic murmur and faint diastolic murmur in mitral area. Lungs, basal crepitations. Liver, enlarged with ascites.

Radioscopy.—Patient too ill for this.

Electrocardiogram.—Auricular flutter (2:1); at times fibrillation.

Course.—The diagnosis was mitral stenosis, auricular fibrillation, congestive heart failure. Operation for hysterotomy and sterilization. Died during the operation (February 1938).

Necropsy.—Viewed externally, great enlargement of the heart affecting mainly R.A. and R.V., the latter forming the entire apex and most of the left border. P.A. greatly dilated, 4·5 cm. in diameter; aorta small, 2·3 cm. in diameter. On opening the heart, R.V. much dilated with little if any hypertrophy. Great dilatation of R.A. and of tricuspid orifice which admits four fingers. There is a large oval defect in the atrial septum, 5 cm. by 3·5 cm. in diameter, its long axis being vertical. A rudimentary atrial septum surrounds the aperture except at its upper margin; anteriorly and below is a firm ridge 1 cm. wide, and posteriorly a thin membrane 0·5 cm. wide. The L.A. about half the size of the right; the L.V. not enlarged. Mitral orifice stenosed and of the button-hole type; the cusps thickened and the chordæ thickened and shortened. Descending aorta small, 1·3 cm. in diameter; right P.A. large, 2·7 cm. in diameter (Fig. 5).

ELECTROCARDIOGRAPHIC CHANGES AFTER ANOXÆMIA AND EXERCISE IN ANGINA OF EFFORT

BY

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Significant changes in the four lead electrocardiogram occur in two-thirds of all cases with angina of effort. This investigation shows that anoxæmia or exercise causes a temporary abnormal change in the electrocardiogram and reduces the number of those with effort angina but with no electrocardiographic abnormality to about 18 per cent.

Details of the Anoxæmia Test.—The subject reclines on a couch and a four lead electrocardiogram is taken, using chest leads IV R and IV F. A close-fitting mask, having inlet and outlet valves and tubes, is strapped to the face. 10 per cent oxygen is inhaled from a rubber bag for three to five minutes. In some of the earlier experiments we used 12 per cent oxygen for ten or fifteen minutes, but it was found that 12 per cent oxygen did not produce anoxæmia sufficiently quickly.

After inhalation for two and a half minutes the tracing was taken with the inhalation continuing; it usually needed two minutes to take, and it was an advantage to have two operators, one to take the tracing and one to regulate the oxygen apparatus and change the leads. 100 per cent oxygen was then given for a minute and the mask removed; fifteen to twenty minutes later another tracing was taken.

The Exercise Test.—The subject walked rapidly up and down a long passage and, in many cases, a short flight of stairs was included. After five or ten minutes of this exercise, a tracing was taken. Usually in the anginal cases the exercise was continued until chest pain occurred. Very much more severe exercise was given to the control cases.

RESULTS

Control Group.—Ten controls consisted of seven normal, healthy medical students, two cases of well-compensated valvular disease, and one case of left mammary pain without organic heart disease. They showed no RS–T changes or T wave inversion. A diphasic T_3 developed in one and the voltage of the T waves was reduced in five. The details were as follows:

Diagnosis	Anoxæmia Test	Exercise Test
Left mammary pain	No change	T_3 flatter
Mitral stenosis	T_3 lower voltage	No change
Aortic incompetence	No change	No change
Normal	No change	No change
Normal	T waves lower voltage	T waves higher voltage
Normal	No change	No change
Normal	No change	No change
Normal	T waves lower voltage	No change
Normal	T waves lower voltage	T waves lower voltage
Normal	T_3 diphasic	No change

Angina of Effort Group.—Twenty cases of angina of effort, in whom the four lead cardiogram showed no significant change, were tested. Six gave abnormal S–T and T wave responses to the anoxæmia test. Eighteen of these were also given the exercise test, and abnormal S–T or T wave changes occurred in eight.

One case gave changes following anoxæmia and none after exercise. Three cases gave none after anoxæmia and S–T and T wave changes after exercise. In those cases giving changes both after anoxæmia and exercise, three showed more marked changes after anoxæmia and five after exercise. Illustrations are shown in Figs. 1–3.

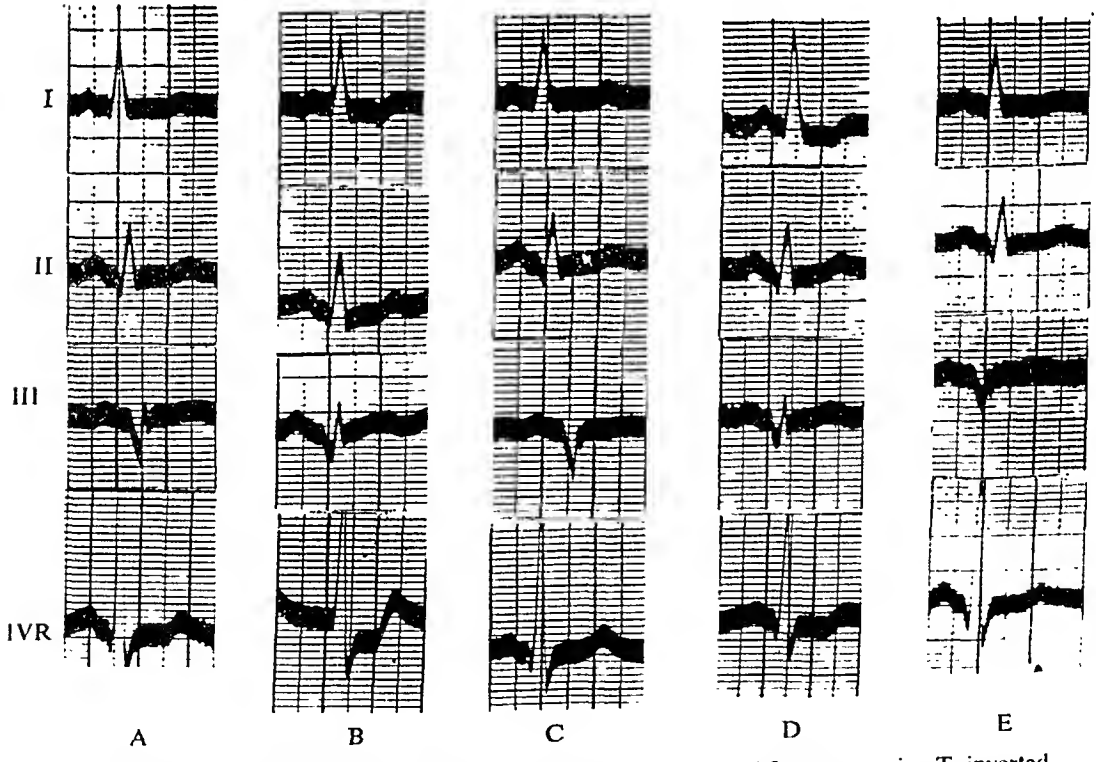

FIG. 1.—(A) Resting electrocardiogram, with Q_3 doubtful. (B) After anoxæmia: T_1 inverted, RS–T_4 depressed and diphasic. (C) Recovery 20 minutes later. (D) After exercise, T_1 and T_4 diphasic, RS–T_1 and RS–T_4 a little depressed. (E) Recovery 20 minutes later.

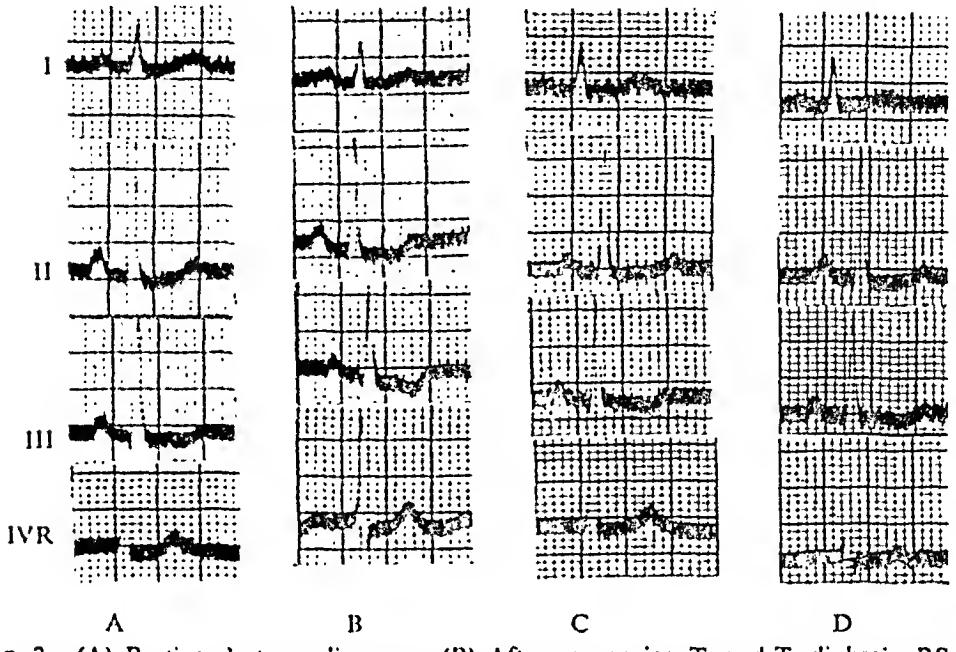

FIG. 2.—(A) Resting electrocardiogram. (B) After anoxæmia: T_2 and T_3 diphasic, RS–T_4 depressed 1·5 mm. (C) Recovery. (D) After exercise. (Note change after anoxæmia, but very little after exercise.)

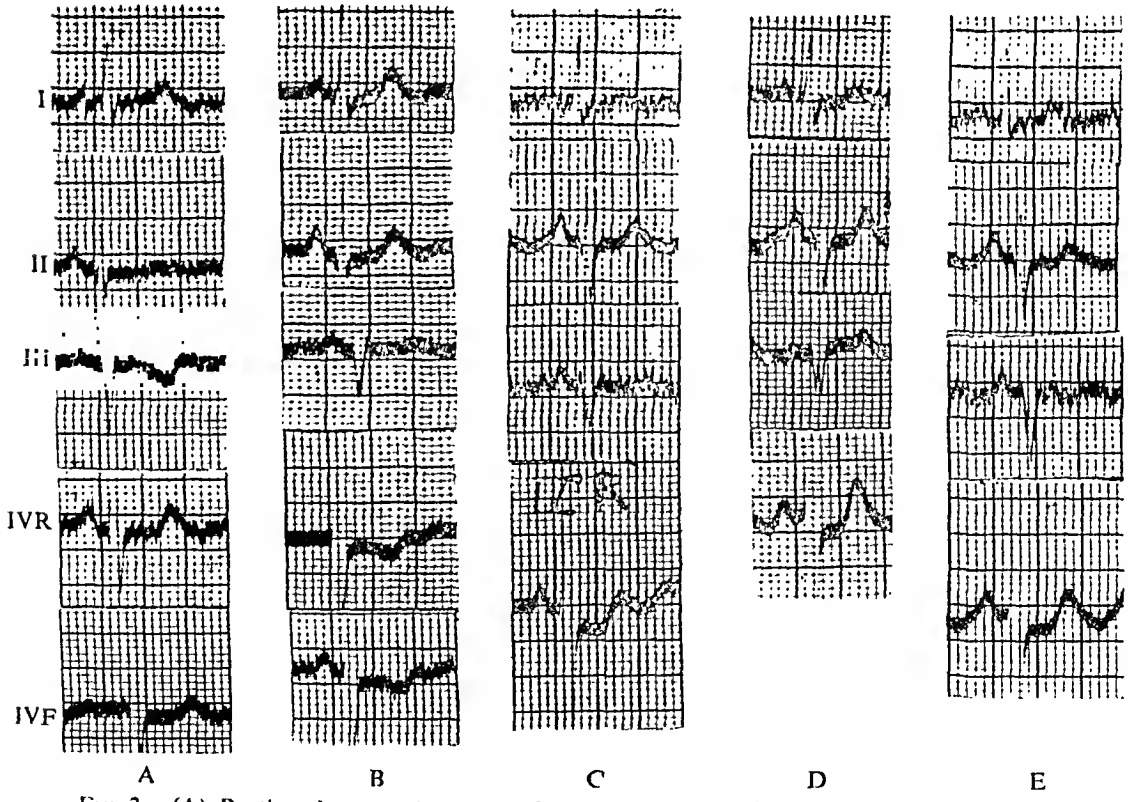

FIG. 3.—(A) Resting electrocardiogram, left axis deviation, T_3 inverted. (B) After exercise, RS–T_4 depressed and T_4 inverted. (C) Two months later, resting electrocardiogram shows depressed RS–T_4 and diphasic T_4. (D) After anoxæmia. (E) After 20 minutes' rest. (Note change after exercise test and some deterioration in the resting tracing two months later; but very little change after anoxæmia.)

To sum up: eleven cases gave no change after anoxæmia or exercise; nine showed some change after anoxæmia or exercise.

The T wave changes were, with one exception, associated with RS–T elevation or depression. Changes in the chest lead occur in a more exaggerated fashion than in the other leads. The details were as follows:

ANGINA OF EFFORT

Case No.	Anoxæmia Test	Exercise Test
1	No change	No change
2	T_2 flatter	No change
3	No change	No change
4	$S–T_2$ depressed, less than 1 mm.	No change
5	T and R lower voltage	Not done
6	No change	No change
7	No change	Not done
8	T waves lower voltage	No change
9	No change	No change
10	No change	No change
11	No change	No change
12	$S–T_2$ & $S–T_4$ depressed 2 mm.	T_2, T_3, & T_4 diphasic
13	$S–T_1$ depressed, T_1 diphasic $S–T_4$ depressed 4 mm., T_4 diphasic	$S–T_4$ depressed 1 mm. T_1 & T_4 diphasic
14	T_1 diphasic	T_1 diphasic. (Died suddenly later)
15	$RS–T_4$ depressed 4 mm.	$RS–T_1$, $RS–T_2$, & $RS–T_4$ depressed, T_1 diphasic, T_4 diphasic
16	$RS–T_2$ & $RS–T_4$ depressed 1·5 mm., T_2 diphasic	$RS–T_2$ depressed 0·5 mm.
17	$RS–T_4$ depressed 4 mm.	$RS–T_1$, $RS–T_2$, & $RS–T_4$ depressed 2 mm. T_4 inverted
18	No change	T_1 & T_2 diphasic
19	No change	Q_2 & Q_3 enlarged $S–T_3$ elevated, $S–T_1$ depressed
20	$RS–T_2$ & $RS–T_3$ depressed 0·5 mm.	T_2 & T_3 diphasic, slight depression $RS–T_2$ & $RS–T_3$

DISCUSSION

In discussing the diagnostic value of the anoxæmia test, it must first be stated that changes in the T wave and the S–T level occur in normal persons if anoxæmia is continued to an extreme degree and long enough. This has been well shown by many observers. Greene and Gilbert (1921), using 6 per cent oxygen, caused collapse, following which there was R-T depression with diphasic and negative T waves, and later, in some cases, an abnormal rhythm. Katz, Hamburger, and Schutz (1933) also found diminution of the T waves, with at times inversion, and also S–T depression in normals and in anginal cases. Rothschild and Kissin (1933) took electrocardiograms after induced progressive anoxæmia in 38 persons: 11 developed deviation of the S–T segment; 8 of these suffered from angina pectoris, 3 did not. May (1939) found flattening of the T wave and occasionally a depression of the S–T segment in normals. Stearn, Drinker, and Shaughnessy (1938) described the cardiographic changes in 22 cases following asphyxia from carbon monoxide poisoning; the tracings were

unfortunately taken only after some treatment with oxygen and carbon dioxide, but 18 showed abnormality of the T wave and in the level of the S–T segment.

The important fact to be gained from these results is that the anoxæmia was of an extreme degree and very much more severe than that made use of in the test described in this paper. Also most of these other workers obtained anoxæmia by re-breathing, so that it was associated with a progressive carbon dioxide accumulation.

No significant changes of S–T level occurred in our series of controls when 10 or 12 per cent oxygen was inhaled for three to five minutes. Scott and Mullins (1940) caused anoxæmia in cats before and after ligation of the left branch of the left anterior descending coronary artery; changes occurred following anoxæmia only after the artery had been ligated. Larsen (1938), using 9 per cent oxygen, found that the T wave may be lowered but never inverted, and that the S–T segment was not lowered more than 1 mm. in 20 normals. Levy, Bruenn, and Russell (1939) found in 66 normals using 10 per cent oxygen that the RS–T segment was not displaced more than 1 mm., that the T wave tends to decrease in amplitude, that in 2 of the 66 T wave reversal occurred without RS–T deviation, and that partial or complete reversal of T in leads II or III was observed in 22 of 66 supposedly normal persons. These authors put as their criteria of an abnormal response the following changes: (1) 'Change in level of the RS–T junction of more than 1 mm. in any lead, its importance being increased if combined with partial or complete reversal in direction of T in leads I or IV F; (2) partial or complete reversal of T in lead I associated with RS–T displacement as small as 0·5 mm. in this lead; (3) complete reversal of T in lead IV F; or (4) partial reversal of T in IV F associated with RS–T displacement. These seem to be the criteria accepted by most authors as an abnormal response to moderate anoxæmia. Larsen (1938) notes that these changes are not pathognomonic of coronary disease, for they may also occur in patients with rheumatic heart lesions, certain endocrine disorders, and severe anæmia.

In comparing the criteria of an abnormal response following anoxæmia with that following the exercise test, Schott (1939) takes as an abnormal response to the exercise test depression of the RS–T segment of more than 1 mm., inversion of a positive T wave, gross deformation of the S–T interval, and diphasic T waves. Paddu (1938) found only slight change in normals after exercise; especially RS–T depression of about 1 mm. Other recent papers on anoxæmia and the anginal symptoms are those of Rothschild and Kissin (1933), and of Levy, Barach, and Bruenn (1938). Riseman, Waller, and Brown (1940) cast considerable doubt on the diagnostic value of the anoxæmia and exercise tests —without, in the authors' view, very good reasons for their opinion.

Comparison of Anoxæmia and Exercise Tests

The exercise test appears to give significant changes as often and probably more often than the anoxæmia test, and is much more easily done, as no special apparatus apart from the electrocardiograph is needed. On the other hand, the

anoxæmia test may show an abnormal change when the exercise test is negative. Also a certain number of patients cannot be persuaded to exercise strenuously.

The response to exercise and anoxæmia in normals and in coronary cases is similar in each test, with this exception: that in normals after the exercise test the T wave tends to be increased in voltage, while after inhalation of 10 per cent oxygen the T wave tends to be reduced in voltage. The increase in voltage after exercise is due, according to Scherf and Boyd (1940), to an increased sympathetic tone. It had been hoped that these tests would give changes conforming to the T_1 or T_3 type of coronary curve, so that it would be possible to say which part of the heart was diseased, but only in a few instances did the response give a characteristic localizing change.

Summary

One-third of all cases with angina of effort show no changes in the four lead electrocardiogram.

Nearly half this group with no cardiographic abnormality give changes suggestive of myocardial disease following anoxæmia with 10 per cent oxygen for three to five minutes or after an exercise test.

The abnormal and normal response to anoxæmia and exercise are described and discussed.

The exercise test gives an abnormal response slightly more often than the 10 per cent anoxæmia test, but changes may occur after anoxæmia when none follow after exercise.

This investigation was carried out in the Cardiographic department of St. Bartholomew's Hospital and more recently at the Royal Chest Hospital, City Road. One of the authors received a grant from the Medical Research Council.

References

Greene, C. W., and Gilbert, N. C. (1921). *Arch. intern. Med.*, 27, 517.
Katz, L. N., Hamburger, W. W., and Schutz, W. J. (1933). *Amer. Heart J.*, 9, 771.
Larsen, Kaj. H. (1938). *Iltmangel*, Copenhagen.
Levy, R. L., Bruenn, H. G., and Russell, N. (1939). *Amer. J. med. Sci.*, 197, 241.
Levy, R. L., Barach, A. L., and Bruenn, H. G. (1938). *Amer. Heart J.*, 15, 187.
May, S. H. (1939). *Ibid.*, 17, 655.
Paddu, V. (1938). *Cardiologia*, 2, 183.
Riseman, J. E. F., Waller, S. V., and Brown, M. G. (1940). *Amer. Heart J.*, 19, 683.
Rothschild, M. A., and Kissin, M. (1933). *Ibid.*, 8, 729.
—— (1933). *Ibid.*, 8, 745.
Scherf, D., and Boyd, L. J. (1940). London.
Schott, A. (1939). *Guys' Hosp. Rep.*, 89, 387.
Scott, W. S., Jr., Leslie, A., and Mullins, M. G. (1940). *Amer. Heart J.*, 19, 719.
Stearn, W. H., Drinker, C. K., and Shaughnessy, T. J. (1938). *Ibid*, 15, 434.

VARIABLE VENTRICULAR COMPLEXES IN HEART BLOCK, AND THEIR RELATION TO BILATERAL BUNDLE BRANCH BLOCK

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Variable ventricular complexes in heart block have been recorded by a number of writers since they were first described by Mathewson (1913). King (1934) found them in five out of thirty-six cases with the double lesion of complete heart block and bundle branch block. Cohn (1913) noted both left and right bundle branch block and transitional complexes in a case passing from partial to complete A-V block, and he suggested that the changes might be due either to depression of conductivity in both branches alternately or else to a wandering pacemaker. Gilchrist and Cohn (1928) thought the latter explanation the more likely, and attributed the transitional complexes to the almost synchronous discharge of impulses from centres in each ventricle. Similar views have been expressed by Willius (1924), by Coelho (1932), and by Scherf and Schott (1932). On the other hand, Mathewson considered that in his case the impulse was being conducted alternately by each branch.

The diagnosis of bilateral bundle branch block was first made by Cohn and Lewis (1912) in a patient who had suffered from many Stokes-Adams attacks and was found at autopsy to have both branches divided from each other and from the main stem; the QRS was widened to ·2 sec., which they thought might be characteristic of the condition. Faulkner (1932) also gives bilateral bundle block as an explanation of a wide QRS without axis deviation. However, in a similar case of separation of the branches from each other and from the main stem reported by Don, Grant, and Camp (1932) variable ventricular complexes occurred without gross widening of the QRS and they attributed the changes to a shift in the pacemaker from one ventricle to the other.

The suggestion that lesions are more likely to be found in the bundle branches than in the main stem, when variable ventricular complexes accompany A-V block derives from the experimental work of Wilson and Hermann (1921). When both branches of the bundle had been cut in dogs, they found that standstill of the ventricles only lasted a few minutes, after which centres in each ventricle took over. The resulting complexes might be of either branch block

type or might be normal. Transitional complexes they ascribed to the interplay of two centres, one on each side of the heart, which were not discharging their impulses synchronously. When one branch started to recover, incomplete A-V block occurred for a time combined with bundle branch block that was permanent. Interest in this conception of bilateral bundle branch block was revived by Yater, Cornell, and Clayton (1936), who made histological studies in three cases of heart block with varying ventricular complexes; in one they found that both branches were destroyed, while in the other two there was extensive disease in each of the branches ; in all three the main stem was relatively healthy: they concluded that in all cases of heart block associated with variable ventricular complexes the pacemakers are situated in the ventricles below lesions in the branches, and that the leadership of the pacemaker changes from one side to the other.

Four such cases have been recently observed. Two were usually associated with complete A-V block ; in two the A-V block varied. When dealing with ventricular centres a difficulty arises, since a rhythm originating in a bundle branch is designated by a term that indicates disease in the other branch, which may not be present. To avoid confusion, the classical terminology of bundle branch block adopted by the Criteria Committee of the New York Heart Association (1939) has been followed in describing the cases, except that a QRS of ·12 sec. has been deemed sufficiently long to justify a diagnosis of bundle branch block. But in the discussion curves will usually be described according to the branch through which conduction takes place.

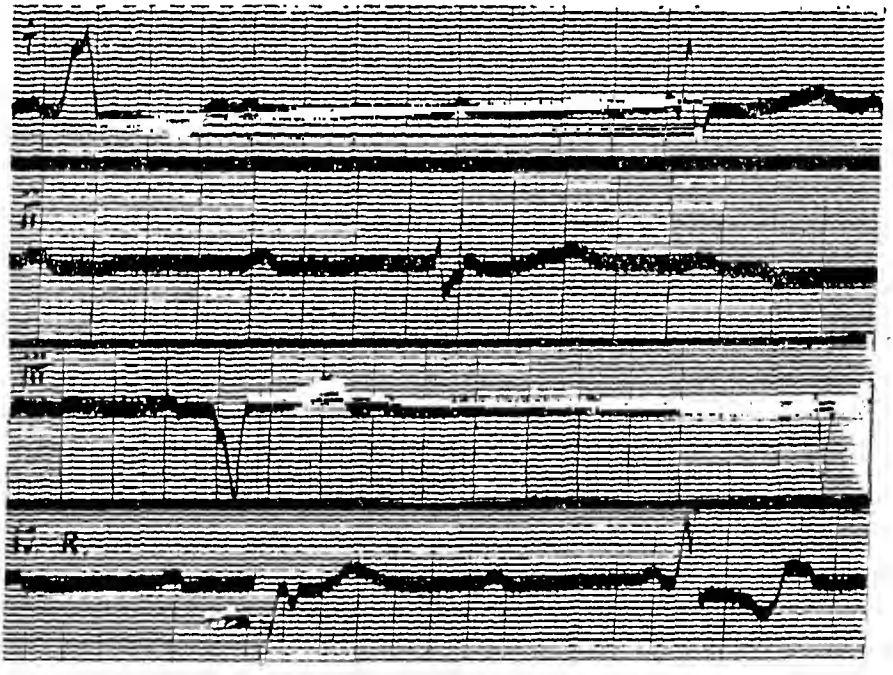


FIG. 1.—Case 1. 14,7,39. Complete A-V block with a ventricular rate of 26. Alternate left (discordant type, QRS ·15 sec.) and right (type B, QRS ·12 sec.) branch block. Note inverted P deforming S–T interval in first complex of lead IVR. (See p. 78.)

NOTES OF THE FIRST CASE

A man of 67 had noticed dyspnœa on exertion for two months. His pulse rate was 32. A musical systolic murmur was audible at the apex, and a harsh systolic murmur at the aortic base. The heart was a little enlarged to the left; the ascending aorta was prominent; the blood pressure was 190/110; and the Wasserman reaction was negative. He was taken into hospital in July 1939

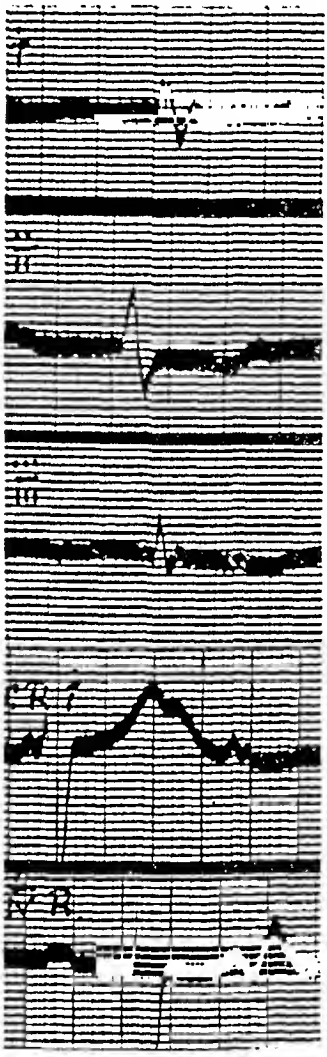


FIG. 2.—Case 1. 25,7,39. Complete A-V block. Low voltage curve of right-sided type (QRS ·11 sec.).

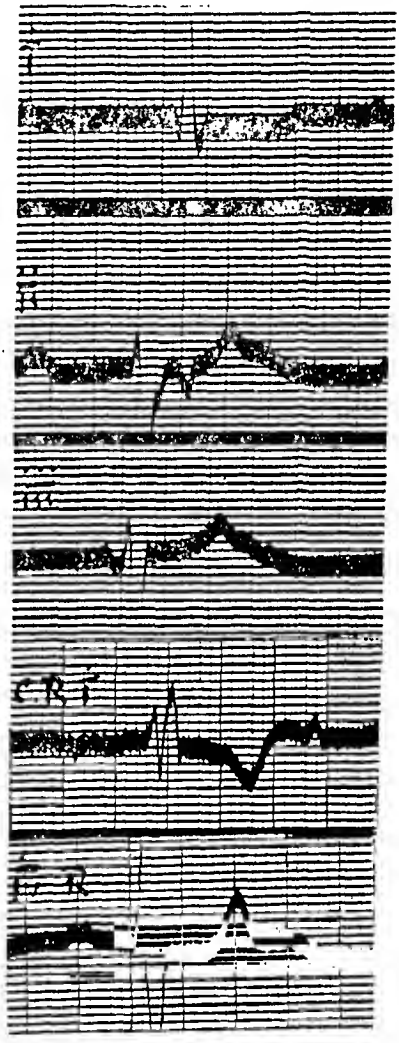


FIG. 3.—Case 1. 1,8,39. Complete A-V block. Right branch block (type B, QRS ·12 sec.). Note inverted P deforming S–T interval in lead II.

for observation. Ephedrine had no effect upon the ventricular rate, and he now maintains fair health upon moderate doses of digitalis. He has never had Stokes-Adams attacks.

Numerous electrocardiograms taken during his stay in hospital and since his discharge all showed complete A-V block. The P waves were not very

regular and were sometimes flattened. On six occasions early inverted P waves deformed the S–T period, indicating retrograde conduction from ventricle to auricle. They all followed the R wave by ·16 to ·18 sec., and occurred when the interval between the preceding P and the R was from ·50 to ·58 sec. (Figs. 1 and 3).

The ventricular complexes varied. Fig. 1 shows complexes of left and right branch block. The left branch block complexes are of the discordant type and they have a QRS of ·15 sec. The right branch block complexes are of type B and have a QRS of ·12 sec. The ventricular rate is 26 and regular. No transitional complexes are present.

After rest the left branch block complexes disappeared, and their place was taken by a low voltage curve of right-sided type with a QRS of ·11 sec. at a rate of about 30 (Fig. 2), which has alternated with the right branch block (Fig. 3) since.

Injection of ·5 c.c. adrenaline at a time when the low voltage curve was present led to an acceleration of eight beats (from 30 to 38). No premature beats were seen, but the following changes were observed: After three minutes the curve returned to right branch block, type B; after eight minutes two complexes, with a normal QRS of ·07 sec. occurred (Fig. 4): at ten minutes

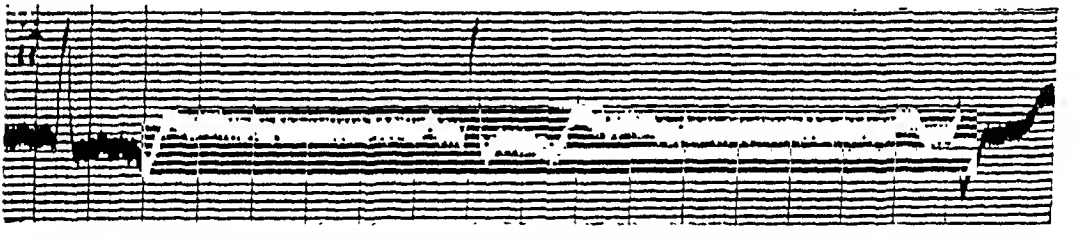


FIG. 4.—Case 1. 25,7,39. Showing two complexes with QRS of ·07 sec., 8 minutes after injection of ·5 c.c. of adrenaline.

the low voltage complexes were again present, but from thirteen minutes onward the curve returned to right branch block, type B.

Summary.—In a man with complete heart block in the forward direction but with evidence of retrograde conduction at times from ventricle to auricle, the following changes in the ventricular complexes were observed.

1. Left bundle branch block (QRS, ·15).
2. Right bundle branch block of type B (QRS, ·12).
3. Low voltage curve of right sided type (QRS, ·11).
4. Normal QRS (·07) after adrenaline.

NOTES OF THE SECOND CASE

A man of 67 was admitted to the Harrogate General Hospital in June 1939. He had been conscious of dyspnœa on exertion since an attack of influenza two months previously. He had experienced three attacks of unconsciousness during the previous two days.

The pulse rate was 32. There were no murmurs, but auricular sounds

were audible at the apex. The heart was considerably enlarged to left and right, the cardio-thoracic ratio being 16 cm./28 cm. The blood pressure was 200/70. The Wasserman reaction was negative.

He was allowed to get up, but he then complained of dizziness, and the pulse rate was found to have fallen to 26. He was given ephedrine, gr. ii daily, and the pulse rate subsequently fluctuated from 32 to 36. He was discharged in fair health, but later Stokes-Adams attacks recurred and he died in one in May 1940.

Most of the electrocardiograms showed complete A-V block ; incomplete (2: 1) A-V block occurring only at the end of, and for a short time after, his stay in hospital. On six occasions, when complete A-V block was present, early inverted P waves deformed the S–T period, indicating retrograde conduction from ventricle to auricle. They all followed the R wave by ·16 sec., and occurred when the interval between the preceding P and the R was from ·42 to ·50 sec. (Figs. 5, 6, and 13).

Fig. 5, taken on admission, shows complete A-V block at a rate of 37 and

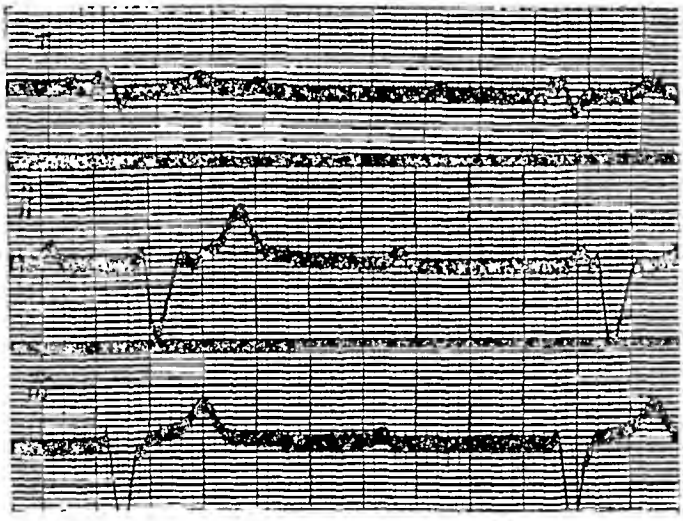


FIG. 5.

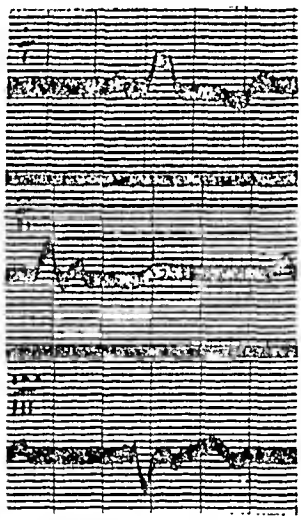


FIG. 6.

FIG. 5.—Case 2. 16,6,39. Complete A-V block. A typical right branch block (QRS, ·14 sec.). Inverted P wave deforms S–T interval of first complex in lead II.

FIG. 6.—Case 2. 22,6,39. Complete A-V block. Left branch block (QRS, ·12 sec.). Inverted P wave deforms S–T interval in lead III.

a bundle branch block with a QRS of ·14 sec., which, though somewhat atypical, has been interpreted as a right branch block in view of the form of the chest leads recorded later (see Fig. 17). Fig. 6, which was taken after the fall in rate had been noted, shows a left branch block of the discordant type, (QRS, ·12) at a rate of 29. For the next week the left branch block persisted, with rates varying from 27 to 32. Adrenaline ·5 c.c. was then given subcutaneously. This had no effect upon the ventricular rate, but after seven minutes a right branch block complex appeared, and after eleven minutes the curve changed to a type A right branch block (QRS, ·14) at a rate of 27 in lead I and of 33 in lead III (Fig. 7).

Three days later the A-V heart block began to lift, and the left branch block complexes now followed P waves with a P–R interval of ·24 sec. At the same time right branch block complexes returned, being still associated with complete A-V block (see Fig. 17 on p. 84). Four days later incomplete (2:1) A-V block became established, both with left (Fig. 8) and right (Fig. 9, leads II and

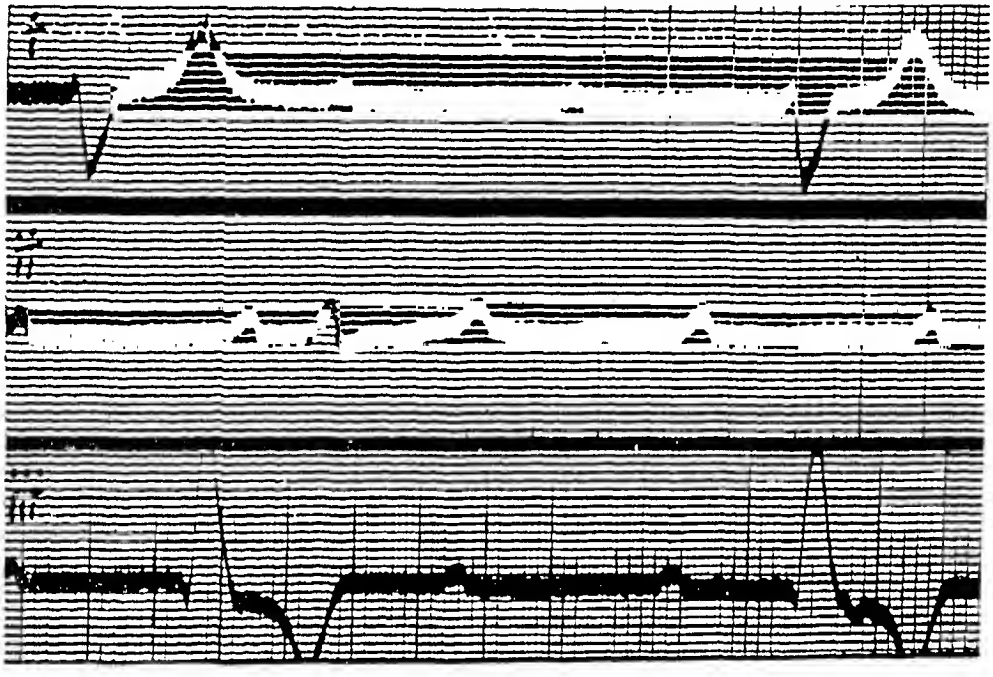


FIG. 7.—Case 2. 28,6,39. Eleven minutes after injection of ·5 c.c. adrenaline. Complete A-V block (V. rate 27 in lead I and 33 in lead III). Right branch block (type A, QRS ·14 sec.).

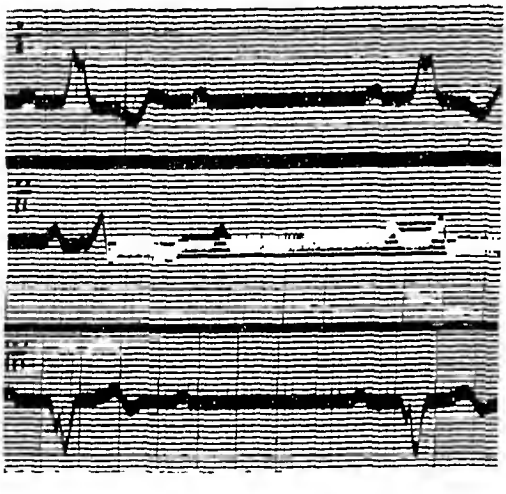


FIG. 8.

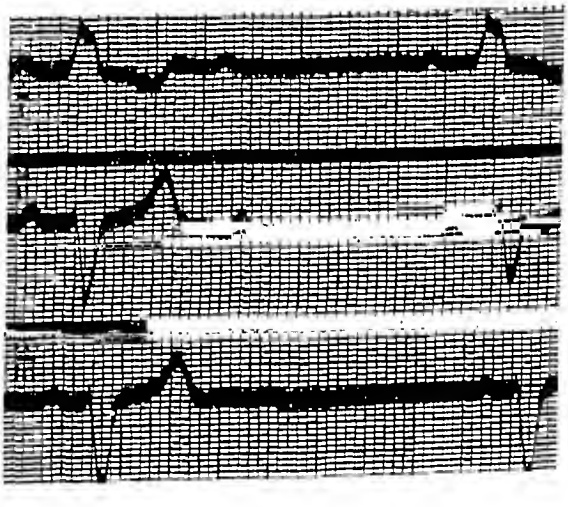


FIG. 9.

FIG. 8.—Case 2. 6,7,39. Incomplete (2:1) A-V block and left branch block (QRS, ·14 sec.).

FIG. 9.—Case 2. 6,7,39. Incomplete (2:1) A-V block with left branch block in lead I and right branch block in leads II and III. There is some variability in the QRS of the complexes in lead II, and of the P–R intervals in lead III.

III) branch block, though there is some variability in the P–R intervals of the right branch block complexes. Incomplete (2: 1) A-V block (with left branch block) persisted for two months, and lead II in Fig. 10 contains a run of three beats of 1: 1 rhythm, the middle beat being a right branch block complex.

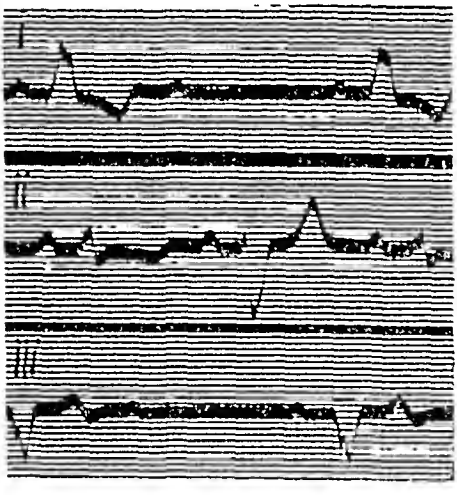


FIG. 10.

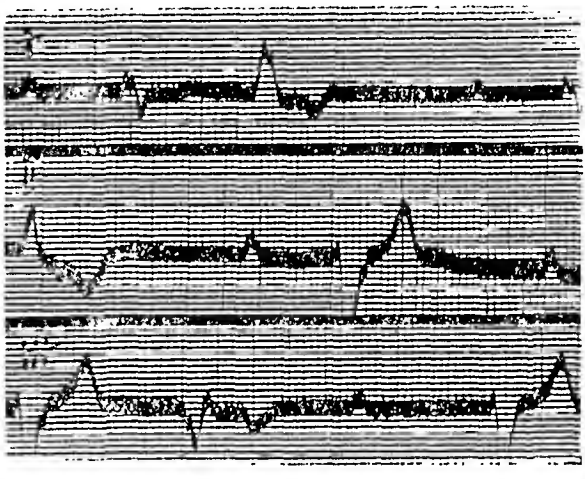


FIG 11.

FIG. 10.—Case 2. 28,7,39. Left branch block with incomplete (2 : 1) A-V block. In lead II a run of three beats of 1 : 1 rhythm occurs, the middle complex being one of right branch block.

FIG. 11.—Case 2. 22,9,39. Complete A-V block. Right branch block. Right ventricular premature contractions. An inverted P deforms the S–T period in the premature beat in lead II.

In September 1939 complete A-V block returned with right branch block, and early beats were seen arising from the right ventricle somewhat dissimilar in form from the left branch block complexes previously observed (Fig. 11). An inverted P deforms the S–T period in the early beat in lead II and again in Fig. 13. Later, a transition from left to right branch block was recorded (Fig. 12), and a change from right to left branch block was obtained ten minutes

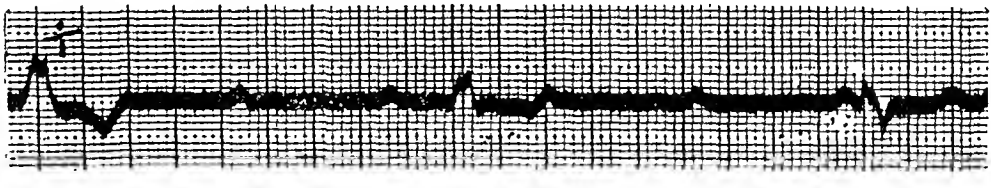


FIG. 12.—Case 2. 13,10,39. Complete A-V block. Transition from left to right branch block.

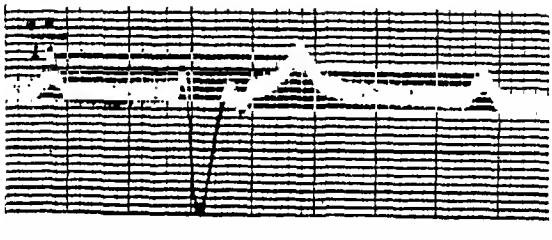


FIG. 13.—Case 2. 19,2,40. Lead II. Complete A-V block. Right branch block. An early and inverted P deforms the S–T period.

after the subcutaneous injection of atropine, gr. 1/30, associated on this occasion with an increase in the rate from 31 to 35.

Summary.—A man who died from Stokes-Adams disease had A-V heart block, usually complete in the forward direction, but with evidence of retrograde conduction at times from ventricle to auricle. The following changes in the ventricular complexes were observed.

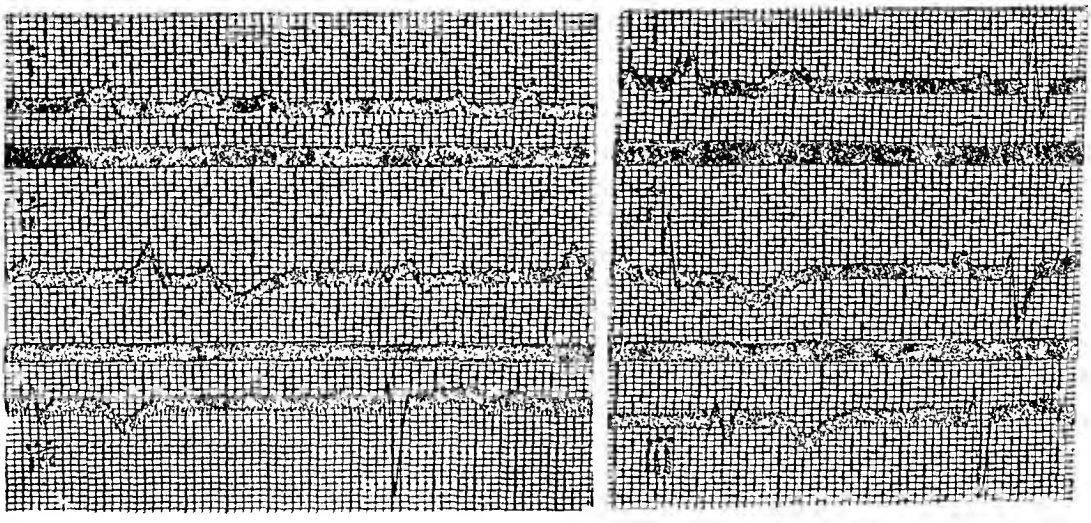
1. Right branch block, atypical (QRS, ·14).
2. Left branch block (QRS, ·12–·14).
3. Right branch block of type A (QRS, ·14) after adrenaline.

Notes of the Third Case

A man of 59 was seen with Dr. Kerr Pringle in October 1937. In 1935 he had developed pernicious anæmia but the blood had been restored to normal. Three weeks previously he noticed a fullness in his neck and became conscious of the beating of his heart, the rate of which was found to be 30. Since then he had been kept in bed.

The heart was not enlarged. There were no murmurs. The blood pressure was 160/110. Cardiograms showed a mixture of complete and incomplete (2:1) A-V block. He was admitted to hospital next day, when it was found that incomplete (2:1) A-V block only was present. Normal rhythm was restored, both by atropine and adrenaline, and was maintained during his stay in hospital with ephedrine. Subsequently he reverted to 2:1 A-V block, but a spontaneous return to normal rhythm took place seven months later and was maintained for a year. In July 1939 complete A-V block returned with a pulse rate of 20. Ten days later he experienced a succession of Stokes-Adams attacks, in one of which he died.

Fig. 14 shows that complete A-V block was associated with left branch block



A B

Fig. 14.—Case 3. 19,10,37. (A) and (B) Left branch block (concordant type, QRS ·14 sec.) associated with complete A-V block at a rate of 30. Also right branch block (type B. QRS ·15 sec.) associated with incomplete A-V block (P–R ·28 sec.). The first complex in lead II in (B) is transitional and has a QRS of ·10 sec.

of the concordant type (QRS, ·14) at a rate of 30, while right branch block, type B complexes (QRS, ·15) followed P waves with a P–R interval of ·28 sec. Their rate (from 33 to 44) is faster than that of the left branch block. In Fig. 14B the first complex in lead II (QRS, ·10, sec.) is transitional. On the following day atropine, gr. 1/30, was given subcutaneously, and Fig. 15

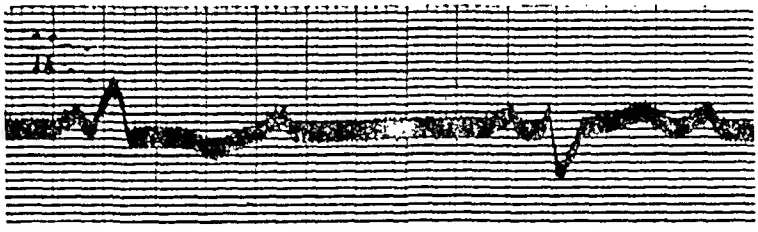


FIG. 15.—Case 3. 21,10,37. After injection of atropine, gr. 1/30. An early beat arises in the right ventricle 5 minutes before restoration of normal rhythm.

shows an early beat from the right ventricle which occurred five minutes before the restoration of normal rhythm. Next day adrenaline (1 c.c.) restored normal rhythm in five minutes, but subsequently induced premature beats from both ventricles (Fig. 16). Six months later, and a fortnight before the spontaneous

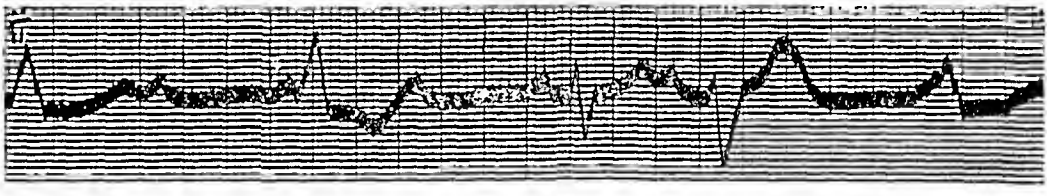


FIG. 16.—Case 3. 22,10,37. Premature beats from both ventricles after injection of 1 c.c. of adrenaline.

resumption of normal rhythm, early beats from the right ventricle occurred again (Fig. 18 on p. 84) and a transitional complex is seen at the end of lead III.

On July 9, 1939, he noticed his heart was acting slowly and his pulse rate was found to be 20. On July 18 he had six Stokes-Adams attacks. When seen on July 19 the pulse was 20, but the apex rate was faster, since there were beats which were not being transmitted to the wrist. While being attached to the cardiograph he had a Stokes-Adams attack. When the apex impulse returned, the rate was 50 and irregular. Fig. 19, taken a few minutes later, shows a return to the left branch block (concordant type) at a regular rate of 44. The QRS is still ·14 sec., but T is now flat in lead II and upright in lead III. The complexes resemble the premature beats from the right ventricle induced by adrenaline rather than the idio-ventricular rhythm of the first record, or the early beats that occurred spontaneously. The Q–T interval is prolonged to ·72 sec., compared with ·60 sec. during the initial phase and ·44 sec. when normal rhythm was present.

Summary.—In a man who died from Stokes-Adams disease complete A-V block was associated with left branch block of the concordant type (QRS of ·14), while incomplete (2:1) A-V block and normal (1:1) rhythm were associated

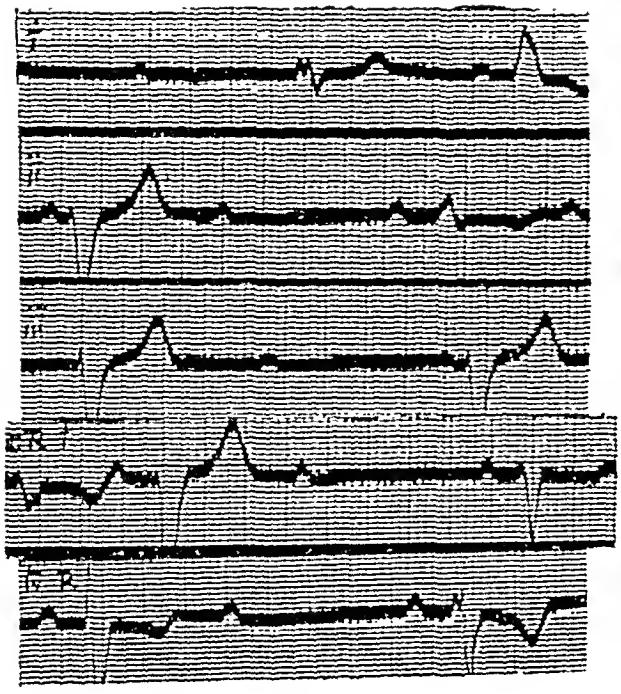


FIG. 17.

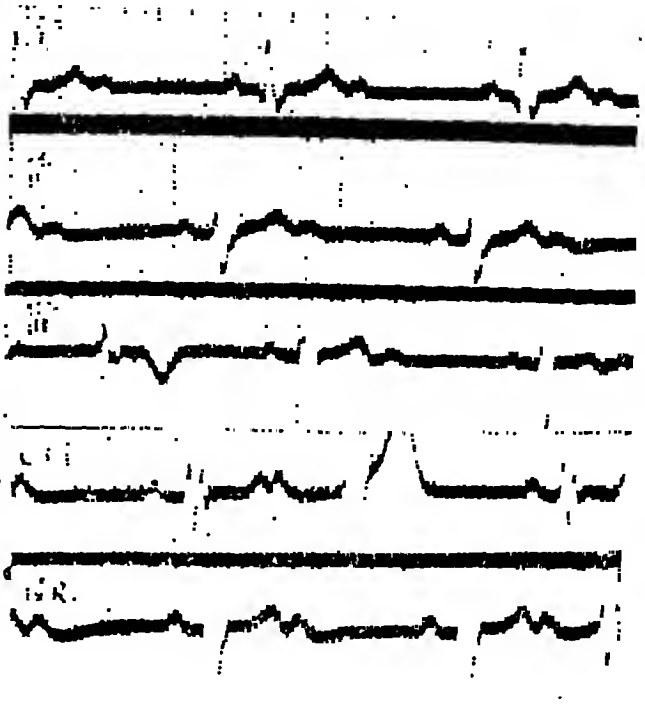


FIG. 18.

FIG. 17.—Case 2. 1,7,39. Alternating right and left branch block in leads I, II, CRI, and IVR. In lead III both complexes are right branch block. The third complex in CRI is transitional. Right branch block is associated with complete A-V block. Left branch block complexes follow P waves with a P–R interval of ·24 sec.

FIG. 18.—Case 3. 22,5,38. Incomplete (2:1) A-V block. Right branch block (type B). Early beats from right ventricle similar to the left branch block complexes of first record seen in leads III and CFI and IVR. The last complex in lead III is transitional.

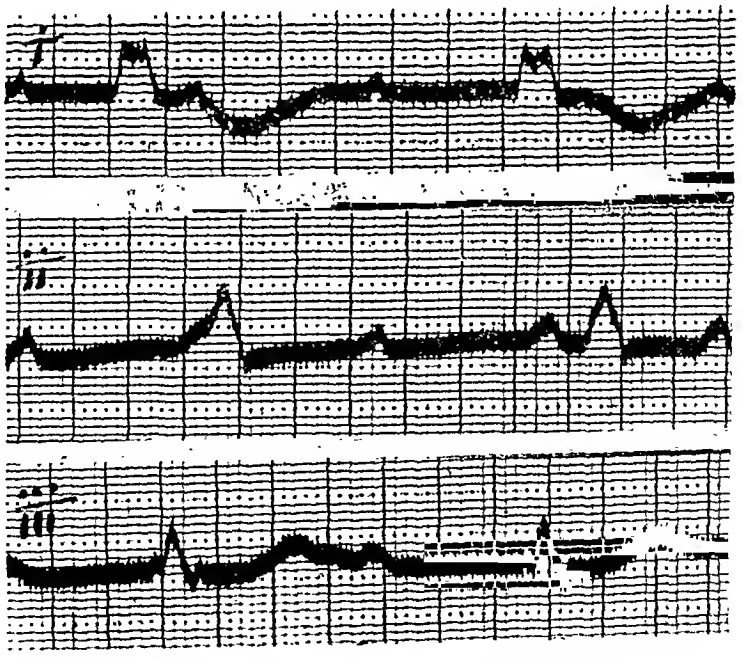


FIG. 19.—Case 3. 19,7,39. Left branch block (concordant type, QRS ·14 sec.). T_2 flat. T_3 upright. Q–T interval is ·72 sec.

with right branch block of type B (QRS, ·15). A transitional complex with a QRS of ·10 sec. was observed.

Notes of the Fourth Case

A man, aged 64, was admitted to the Harrogate General Hospital in September 1936 with a history of increasing dyspnœa on exertion for two years and œdema for ten weeks. Four years previously his gall-bladder had been removed for severe and gripping pains in the upper abdomen. A partial iridectomy for glaucoma was performed in the same year.

He was cyanosed and orthopnœic with œdema in the legs, scrotum, and lumbo-sacral region. The pulse was 96. The blood pressure was 156/110. The heart sounds were faint, with an apical gallop rhythm. The heart was greatly enlarged to the left and right, the cardio-thoracic ratio being 19 cm./33 cm. A tender liver was palpable eight inches below the costal margin. The lungs were congested. The cardiogram showed incomplete A-V block (P–R, ·24 sec.), atypical right branch block (QRS, ·12) with small deflections in lead I, and right ventricular premature beats (Fig. 20). Under digitalis therapy the heart failure disappeared and he was discharged in three weeks.

In November the blood pressure was 120/68. Fig. 21 shows incomplete

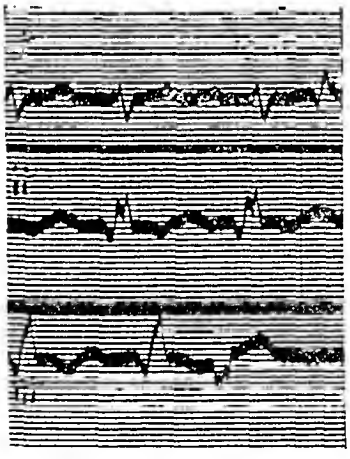


Fig. 20.

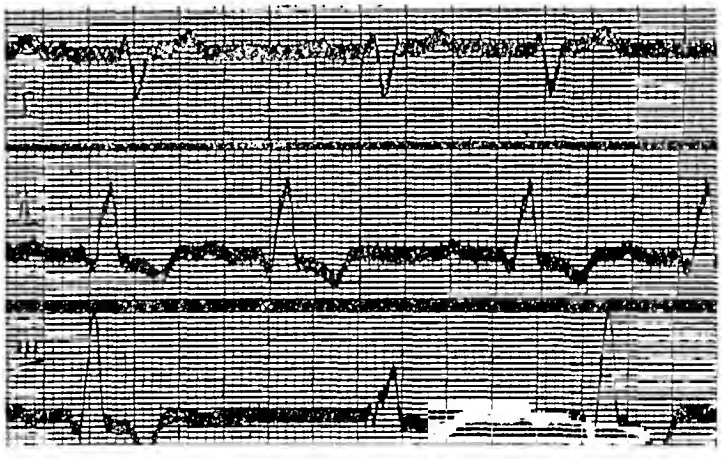


Fig. 21.

Fig. 20.—Case 4. 21,9,36. Incomplete A-V block, (P–R ·24 sec.). Right branch block (atypical; QRS, ·12 sec.). Right ventricular premature beats.

Fig. 21.—Case 4. 6,11,36. Incomplete A-V block (P–R, ·24 sec.). Coupled rhythm probably due to premature auricular beats. Right branch block (type A; QRS, ·14 sec.). In lead III the second complex is an escape of the ventricle following the failure of an auricular beat. It has a form similar to the atypical right branch block of previous record.

A-V block (P–R ·24 sec.); coupled rhythm probably due to premature auricular beats; right branch block of type A (QRS ·14); and a ventricular rate of 68. In lead III an auricular beat fails, and the escaping ventricular complex returns to the atypical right branch block. In January 1937 auricular fibrillation was present (Fig. 22), with a ventricular rate of 42 to 60. The right branch block (type A) is unchanged, and in lead II another atypical right branch block

complex is seen after a long pause. In June 1937 complexes of left branch block (QRS, ·12) appeared in leads I and III, interspersed with the predominant right branch block of type A (Fig. 23). They resembled the premature beats of Fig. 20. By November 1937 the ventricular rate was regular at 40, auricular fibrillation persisting. The QRS of the right branch block had increased to ·16 sec. (Fig. 24).

One morning in June 1938 he had several attacks of unconsciousness and he was admitted to hospital at noon. The pulse was then 36. From 1 p.m. to 2 p.m. he had eleven Stokes-Adams attacks, for which adrenaline was given. From 5.30 to 6 he had five more and at 11 he died in another. Fig. 25 was taken at

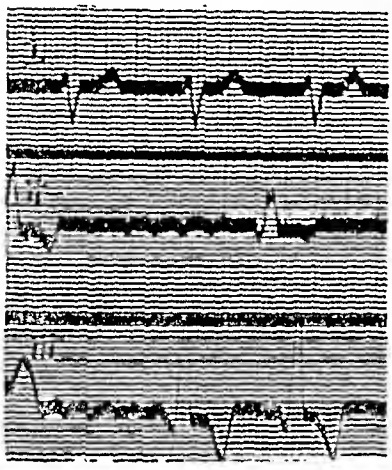


FIG. 22.

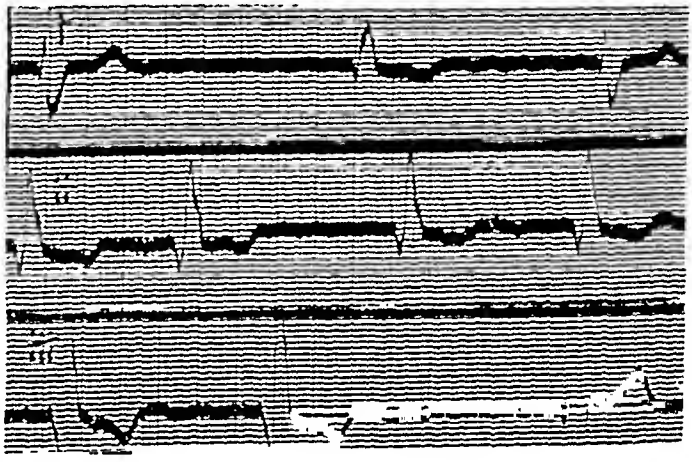


FIG. 23.

FIG. 22.—Case 4. 12,1,37. Auricular fibrillation. Right branch block, type A. The second complex in lead II reverts to the atypical right branch block of Fig. 20.

FIG. 23.—Case 4. 1,6,37. Auricular fibrillation. Right branch block, type A. Left branch block seen in leads I and III, similar to the early beats of Fig. 20.

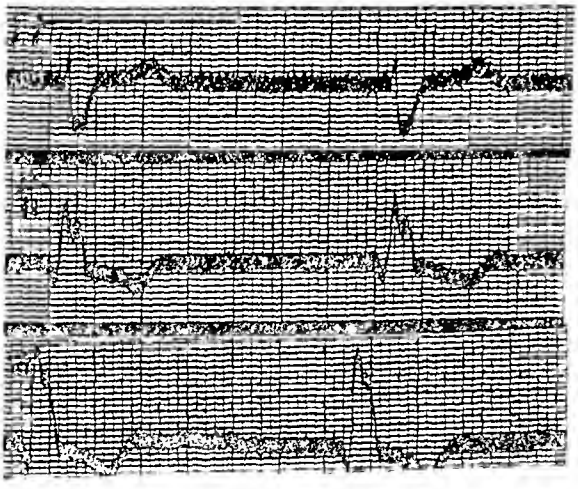


FIG. 24.

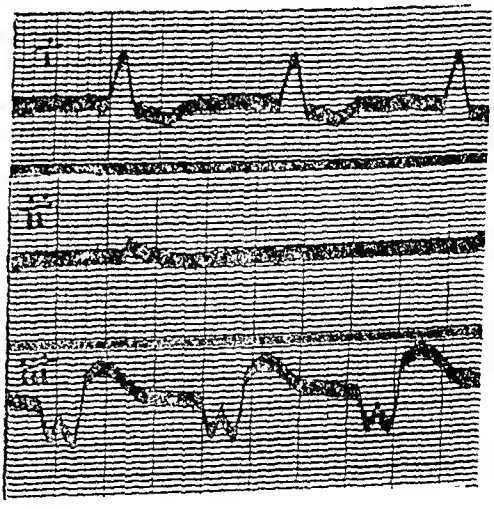


FIG. 25.

FIG. 24.—Case 4. 14,11,37. Auricular fibrillation and complete A-V block (ventricular rate 40 and regular). Right branch block (QRS, ·16 sec.).

FIG. 25.—Case 4. 6,6,38. Left branch block at regular rate of 90. (QRS, ·18 sec.).

1·45, lead II being exposed during a period of unconsciousness. Leads I and III show a left branch block with a regular rhythm at a rate of 90, the QRS being ·18 sec.

Summary.—In a man with congestive heart failure, who died from Stokes-Adams disease, the following changes in the ventricular complexes were observed:

1. Right branch block, atypical (QRS, ·12) with incomplete A-V block (P–R, ·24 sec.).

2. Right branch block of type A (QRS, ·14–·16) with incomplete A-V block and later auricular fibrillation. Atypical right branch block complexes occurred when the ventricle escaped after the failure of an auricular contraction, and after longer pauses when the auricles were fibrillating.

3. Left branch block complexes (QRS, ·12), occurring interspersed with predominant right branch block of type A, and resembling the right ventricular premature beats seen in the first record.

4. Left branch block (QRS, ·18) at a regular rate of 90.

Discussion

Before considering the relation of these curves to bilateral bundle branch block and the evidence in favour of centres in each ventricle as against alternate conduction down each branch it will be advantageous to review the position regarding the width of the QRS.

Duration of the QRS.—Lewis (1925) held that a QRS duration exceeding ·10 sec. was sufficient for the diagnosis of bundle branch block, and this view has been adopted by Hunter, Papp, and Parkinson (1940). With an average normal QRS duration of ·08 sec. this allows ·03 sec. for the impulse to cross the septum. On the other hand, the *Criteria Committee of the New York Heart Association* regard ·13 sec. as the minimum figure for a diagnosis of bundle branch block, which agrees with the statement of Ashman and Hull (1937) that it takes ·05 or ·06 sec. for the impulse to cross the septum. It has sometimes been assumed that bundle branch block is synonymous with obstruction to the passage of the impulse, but this is not so. As Comeau, Hamilton, and White (1938) state: " So long as the conduction time through the damaged branch is greater than that through the intact branch plus the myocardial pathway between the two ventricles, . . . bundle branch complexes will result." It follows that the duration of the QRS will be in part a measure of the conducting powers of the relatively healthy branch. In bilateral disease with bundle branch complexes the accepted minimum must always be exceeded. Bilateral bundle disease appears to be common: Yater (1938) found some disease in each branch in all of the six cases of bundle branch block that he examined. Moreover, the QRS values in his cases confirm the importance of conduction in the

relatively healthy branch. Out of three cases of right branch block, two had a QRS of ·12 sec.: in each the right branch was destroyed, but in one the left branch was "almost normal," while in the other it was "not interrupted." The third case had a QRS of ·16 sec., and here the right branch was destroyed and the left branch was "almost destroyed." In the three cases of left branch block neither branch was destroyed, so the correlation was less good. Evidence that the impulse may need only ·03 or ·04 sec. to cross a septum that is not unduly thick is contained in the study made by Master, Dack, and Jaffe (1938) of bundle branch lesions following coronary occlusions. In two cases (Nos. 4 and 15) a branch block changed after successive occlusions and the QRS increased by ·03 or ·04 sec. on each occasion. In one a QRS of ·10 sec. became ·14 sec. with left branch block after the second attack, and increased to ·18 sec. with right branch block after the third. In all the cases here recorded the QRS width of some of the ventricular complexes exceeded ·13 sec., and it may be that QRS widths of this order signify bilateral conduction defects and that some curves with QRS widths from ·11 to ·13 sec. represent a purely unilateral defect. It has, in fact, been recently suggested that chronic bundle branch block usually results from diffuse changes in both branches and that the type of the block is determined by predominant enlargement of one or other ventricle (Master, Kalter, Dack, and Jaffe, 1940).

Bilateral Bundle Branch Block can be diagnosed with confidence when supra-ventricular impulses pass down each branch alternately, as in Case 2 (Fig. 10). When A-V block is complete the diagnosis is less certain, since it is possible for alternate right and left bundle branch block complexes to be due to the interplay of two ventricular centres, one above a lesion in a branch and the other below it. Thus Fig. 1 (Case 1) might be interpreted as being due to the activity of a centre about the point of division of the bundle, with conduction down the left branch alternating with impulses from a centre below a lesion in the right branch. But it is most unlikely that two ventricular centres would have exactly the same rate, and the characteristic of multiple ventricular centres is the appearance of transitional complexes. In Fig. 1 there are no transitional complexes and the R–R intervals are equal, the changes in the branch block complexes having no effect on the regularity of the rhythm. Moreover, the left branch block complexes with a QRS of ·15 sec. ceased after rest and the curve changed to a low voltage curve of right-sided type with a QRS of ·11 sec., and seven days later, following the injection of adrenaline, the QRS became normal. It would seem that in this patient conduction normally took place down the left branch (*R.B.B.B.*) activating the ventricle in ·12 sec., but in the early stages, by reason of fatigue, this route was not available for the alternate impulses which then passed along the more diseased right branch (*L.B.B.B.*) reaching the ventricle in ·15 sec. When conduction improved with rest the QRS fell to ·11 sec., and it was restored to normal by adrenaline. The factor of fatigue is also important in Fig. 10, which records the only run of normal rhythm obtained from Case 2, since the first complex shows conduction down the right branch (*L.B.B.B.*), the second down the left branch (*R.B.B.B.*) and the third again down the right.

The curves of Case 3 conform to the experimental records of Wilson and Hermann: who found that, when one branch started to recover after both had been cut, incomplete heart block might occur for a time combined with bundle branch block that was permanent. When first seen complete heart block was starting to lift three weeks after an abrupt onset. The ventricle was being activated from a centre in the right branch (*Complete Heart Block* and *L.B.B.B.*), but some supraventricular impulses were coming through at a faster rate with conduction through the left branch (*R.B.B.B.*) (Fig. 14). One complex showed almost normal conduction, due to the simultaneous activation of both ventricles by the two routes. As recovery proceeded incomplete heart block became established, and then normal rhythm, at first under the influence of atropine, adrenaline, and ephedrine, and later spontaneously; but right bundle branch block persisted. The centre in the right branch produced early beats immediately before normal rhythm was restored by atropine and shortly before it returned spontaneously. The rhythm during the final phase of complete heart block with Stokes-Adams attacks was furnished by a second centre which was probably lower down in the right branch since the complexes resembled the premature beats induced by adrenaline.

In Case 4 incomplete heart block (P–R, ·24 sec.) was present in the early records. Later the auricles fibrillated, but it is probable that complete dissociation was present when the ventricular rate became regular at 40 (Fig. 24). Conduction through the ventricle was down the left branch (*R.B.B.B.*) with a gradual increase in the QRS from ·12 to ·16 sec.; but a centre in the right branch was responsible first for early beats (Fig. 20) and later for escapes of the ventricle following longer pauses during auricular fibrillation (Fig. 23). All these complexes had the same form and a QRS of ·12 sec. The final curve (Fig. 25) shows conduction through the right branch, or from a centre in it, at a rate of 90 with a QRS of ·18 sec. In a similar case, Comeau, Hamilton, and White (1938) attributed the new rhythm to irritation of an impulse-forming centre in the diseased branch; but in their case the QRS decreased from ·16 to ·14 sec. with the change in the branch block instead of increasing as here from ·16 to ·18 sec. Moreover, the centre previously active in the right branch had hitherto shown a constant QRS of ·12 sec. It is possible that the quickened rate might be associated with a wider QRS, but it is much more likely that the gradual increase in the QRS of the right branch block complexes was due to increasing difficulty of conduction in the less damaged left branch, and that in the last phase fresh damage in that branch made it necessary for the impulse to travel through the right branch, which had hitherto provided the slower route.

Multiple Impulse-forming Centres in the Ventricle.—In Cases 1 and 2, A-V block was always complete, except for a short time in Case 2. Both, however, showed evidence of retrograde conduction from ventricle to auricle when the time relations with the preceding P waves were favourable, and the R–P interval was ·16 to ·18 sec. It cannot be supposed that an impulse generated below a lesion in a branch sufficiently dense to cause complete forward block could penetrate that lesion, traverse the main bundle, pass through the node and

activate the auricle in ·16 sec. The variable branch block complexes in these cases cannot, therefore, be explained by postulating ventricular centres below lesions in the branches. Moreover, in Case 2 the complexes did not alter during the phase of incomplete A-V block when the ventricles were responding to supraventricular impulses. However, in this patient conduction through the left branch (*R.B.B.B.*) changed after a spell of dizziness to conduction through the right branch (*L.B.B.B.*) at a slower rate, and the rate with conduction through the right branch was always rather slower during complete A-V block than with conduction through the left, except once after atropine. Many transitional complexes were also observed. Most of these were minor alterations in shape affecting chiefly the right branch block complexes (Fig. 9, lead II), but an intermediate complex is seen in Fig. 12 which shows transition from left to right branch block. The evidence suggests that two ventricular centres were active, while complete A-V block was present, but that both were above the lesions in the branches. In Case 3 transitional complexes, one with an almost normal QRS, point to a ventricular centre in the right branch in addition to the supra-ventricular impulses which passed along the left branch; and another centre in the right branch was responsible for the rhythm during the last phase. Case 4, too, had a second impulse-forming centre in the right ventricle which produced premature beats, and later, escapes of the ventricle. These three patients all died from Stokes-Adams disease.

In Case 1 there was no evidence of a second ventricular centre. No transitional complexes were seen, no variations in speed between the right and left branch block complexes, and no premature beats. It is difficult to avoid the conclusion that in this case a single centre above the point of division of the bundle was responsible for all the complexes observed with variable conduction down each branch. This patient had no Stokes-Adams attacks.

Curves of Incomplete Bundle Branch Block.—The increase in the QRS of the right branch block complexes in Case 4 was associated with a change in their form. The early curves with a QRS of ·12 sec. had small deflections, especially in lead I; the later curves were of the classical type A right branch block. There can be little doubt that the first type represent a less complete form of right branch block, since they reappeared as escapes of the ventricle on those occasions when the conducting tissue had more time in which to recover owing to the failure of an auricular contraction (Fig. 21). The right branch block curves of Case 2 (QRS, ·14) similarly had small deflections in lead I, and they changed to right branch block of type A after adrenaline. The fibre was under continuous observation from the time of the injection and no cessation of ventricular activity was seen. The rate of the type A complexes in lead I was 27, which is less than the rate before injection. The complexes appeared to be due rather to a change in the path of the impulse than to the activity of a new centre.

It has been suggested that curves with a QRS width between ·10 and ·12 sec. should be interpreted as incomplete bundle branch block, but with bilateral disease the width of the QRS can bear only a limited relationship to the completeness of the bundle branch block. Lewis (1925) was of the opinion that

delay in conduction down one branch could modify considerably the form of the cardiogram, and it is probable that some of the atypical forms recently interpreted as right branch block may in reality signify incomplete bundle branch block, the widened QRS being due to bilateral disease.

Summary and Conclusions

Four cases of A-V heart block with varying ventricular complexes have been observed. In two the A-V block was nearly always complete, although retrograde conduction occurred at times from ventricle to auricle; in the other two the A-V block varied. Analysis of the curves obtained suggests that bilateral bundle conduction defects were present in all of these cases. In three the evidence pointed to multiple centres of impulse formation, and these all died from Stokes-Adams disease; in one it was concluded that variable conduction was taking place down each branch from a single idio-ventricular centre, and he has had no Stokes-Adams attacks.

1. Varying ventricular complexes in A-V heart block usually signify the presence of bilateral bundle conduction defects.

2. The impulses may arise from one or more places in the ventricles. Multiple foci of origin increase considerably the risk of Stokes-Adams attacks.

3. The duration of the QRS in bundle branch block is in part a measure of the speed of conduction in the relatively healthy branch: in bilateral bundle lesions the accepted minimum must always be exceeded. In those cases in which one branch is conducting normally, this minimum width may not exceed ·11 sec.

4. Some forms of atypical right branch block may represent incomplete right branch block, the wide QRS being due to the presence of bilateral defects.

References

Ashman and Hull (1937). *Essentials of Electrocardiography*, p. 46.
Coelho, E. (1932). *Arch. Mal. Cœur.*, **25**, 695.
Cohn, A. E. (1913). *Heart*, **5**, 5.
—— and Lewis, T. (1912). *Ibid.*, **4**, 15.
Comeau, W. J., Hamilton, J. G. M., and White, P. D. (1938). *Amer. Heart J.*, **15**, 276.
Don, C. S. D., Grant, R. T. and Camp, P. D. (1932). *Heart*, **16**, 145.
Faulkner, J. M. (1932). *Med. Clin. N. Amer.*, **15**, 998.
Gilchrist, A. R., and Cohn, A. E. (1928). *Amer. Heart J.*, **3**, 146.
Hunter, A., Papp, C., and Parkinson, J. (1940). *Brit. Heart J.*, **2**, 107
King, J. T. (1934). *Amer. J. Med. Sci.*, **187**, 149.
Lewis, T. (1925). *Mechanism and Graphic Registration of Heart Beat*, pp. 45, 133.
Master, M. A., Dack, S., and Jaffe, H. L. (1938). *Amer. Heart J.*, **16**, 283.
—— Kalter, H., Dack, S., and Jaffe, H. L. (1940). *Ibid.*, **20**, 186.

Mathewson, G. D. (1913). *Heart*, 4, 385.
New York Heart Association (1939). *Criteria for Diagnosis of Diseases of the Heart*, p. 132.
Scherf, D. and Schott, A. (1932). *Klin. Wschr.*, **11**, 945.
Willius, F. A. (1924). *Ann. Clin. Med.*, 3, 129.
Wilson, F. N. and Hermann, G. R. (1921). *Heart*, 8, 229.
Yater, W. M. (1938). *Arch. intern. Med.*, 62, 1.
—— Cornell, V. H. and Clayton, T. (1936). *Ibid.*, 57, 132.

HYDROTHORAX IN HEART FAILURE

BY

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The term "hydrothorax" was applied to clear, non-purulent, pleural effusions before percussion and auscultation were practised and before the signs of heart disease were known. The diagnosis then depended entirely on symptoms, and MacLean (1810) in an early treatise on hydrothorax wrote as follows: "when respiration is considerably impeded, especially on motion, in a horizontal posture, or on ascending an acclivity, when the countenance is at the same time pale and sallow, assumes a leaden or livid hue; the urine small in quantity, high coloured, and, on cooling, deposits a reddish or pink-coloured sediment; the pulse irregular or intermitting; the feet, ankles, or hands swell and are colder than natural; and the patient is suddenly roused from sleep by a sense of suffocation or extreme anxiety about the praecordia, attended with palpitation; the most superficial observer will have no doubt of the presence of a watery fluid in some of the cavities of the chest, and that the person thus affected labours under the disease termed hydrothorax, or dropsy of the chest."

Morgagni (1761) described the association of hydrothorax with heart disease post-mortem and thought that, of the two, the heart lesion was more likely to be the primary condition ; but it was Corvisart (1818) who first really distinguished between hydrothorax consecutive to heart failure and idiopathic or essential hydrothorax, i.e. pleurisy with effusion. He pointed out that cardiac hydrothorax was always associated with ascites and general anasarca Laennec (1826), though he gave an admirable and separate account of pleurisy with effusion, still recognized the two varieties of hydrothorax described by his teacher. Idiopathic hydrothorax was unilateral; symptomatic or secondary hydrothorax was bilateral and usually a terminal condition. He seems to have regarded the absence of adhesions and false membrane as the essential criterion of hydrothorax, though he admitted that the distinction from chronic pleurisy was often as difficult in the cadaver as during life, and mentioned inflammatory hydropsies as having been described. Comte (1822), in his treatise on hydrothorax, does not appear to have recognized heart disease as the cause, though signs of heart failure were often mentioned and digitalis was advocated in treatment. He regarded the palpitation and irregular pulse as due to pressure

on the heart and therefore as characteristic of left hydrothorax or hydropericardium.

The term "cardiac pleurisy," introduced by Bucquoy (1882) and Forgeot (1885), soon became current in France, and papers by Robert (1897), Barié (1902), Rénon (1905), Roubier and Thévenet (1906), Sergent (1925), and Joly (1935) may be mentioned as important in this connection.

A distinction was drawn between hydrothorax due simply to transudation and cardiac pleurisy regarded as an inflammatory exudate secondary to pulmonary infarction, sub-pleural hæmorrhage, congestion or acute œdema of the lung (Huchard), pericarditis, or perihepatitis. This distinction depended partly on clinical considerations and partly on the nature of the effused fluid, namely, its specific gravity, chemistry, and cytology. In general, a bilateral effusion was regarded as a transudate and a unilateral one as an exudate, though it was recognized that pleural obliteration might occasionally explain a unilateral transudate of the opposite side. Beaufumé (1907) established the occurrence of unilateral hydrothorax by describing sixteen cases, in all of which the aspirated fluid had the properties of a transudate. Later, Steele (1904), Joly (1935), and others found it impossible to separate the pleural effusions of heart failure into transudates and exudates, since the qualities of the fluid were often intermediate between these two, corresponding to a " mixed type " of effusion, and our experience confirms this view.

It is now generally stated that hydrothorax is either bilateral or right-sided, which teaching dates back to the last century (Wintrich, 1854) and receives a measure of support from statistics furnished by Steele (1896, 1904), Stengel (1901), Beaufumé (1907), Lickint (1928), Joly (1935), and others, based on clinical or post-mortem findings. Scherf (1936), reflecting the view of the Vienna school, states that hydrothorax is bilateral or right-sided except under certain specified conditions, namely, obliterative pleurisy on the right side, left pulmonary infarct, or pericardial effusion, when a left unilateral hydrothorax may occur.

Present Investigation

In the course of routine X-ray examination of patients with heart failure, and especially while investigating the lung stasis of left heart failure, we have encountered left unilateral hydrothorax in many cases where pulmonary infarction seemed excluded, and far more frequently than can be explained in terms of the views already mentioned. In the absence of any recent statistics based on radiological diagnosis, we have investigated the distribution of hydrothorax anew. In doing so, we have included all serous pleural effusions developing coincidentally with heart failure, for which no extracardiac cause was evident. Effusions associated with pulmonary infarction and heart failure have not been excluded because we believe they are essentially transudates.

The incidence and distribution of hydrothorax was analysed in 356 cases of congestive failure (including left heart failure) encountered at the Middlesex Hospital, the National Hospital for Diseases of the Heart, and in practice.

Radioscopy (or orthodiagram) was done as a routine in all out-patients and in those seen in the consulting room; radiography was carried out later in most cases.

An additional analysis has been made of the post-mortem findings in 109 consecutive cases dying from heart failure, from the records of the Bland-Sutton Institute of Pathology over a period of five years.

Diagnosis

It has been stated that in hydrothorax the clinical signs of fluid in the chest may be scanty in relation to the volume of the effusion. Certainly the interpretation of physical signs is complicated in heart failure by elevation of the diaphragm from abdominal distension. Swelling of the liver tends to exaggerate the higher level of dullness at the right lung base and may suggest fluid there when none is present, or may neutralize dullness due to a small left hydrothorax. Error in the opposite sense arises when basal dullness is wrongly attributed to pulmonary œdema which, as Laennec taught, is imperceptible to percussion. Basal râles due to pulmonary œdema usually persist with a small hydrothorax, and pleural friction is common apart from infarcts, especially when the fluid is being absorbed. Because of the difficulties mentioned, X-rays are essential for the sure detection of small effusions; but if clinical signs of fluid are methodically sought in every case of heart failure, even if œdema is absent, a hydrothorax of appreciable size need rarely be overlooked.

Even a small hydrothorax can be recognized with certainty by radioscopy, which is far superior to radiography in this respect. In screen examination the tube can readily be centred at the upper level of the effusion, and this, combined if necessary with rotation of the patient into the oblique position, usually permits a sharp fluid level to be visualized. In films, taken with the tube centrally placed, a small effusion is often ill-defined and difficult to distinguish from congested lung or thickened pleura. In a small or medium-sized hydrothorax the fluid is mobile and fluctuates freely with movements of the diaphragm, thus making easy its distinction from pleural adhesions or lung opacities. In left hydrothorax the diaphragm is often depressed, so that the size of the effusion will be underestimated unless the left dome of the diaphragm is rendered visible by inflating the stomach with gas, which may be done as a routine by giving alternate draughts of sodium bicarbonate and tartaric acid in solution (Figs. 1 & 2 on pp. 96 & 97).

Incidence of Hydrothorax

In 356 consecutive cases of heart failure, hydrothorax was observed at some stage or other in 136 (38·5 per cent). This series includes patients with failure when first seen and others who developed failure while under observation. The diagnosis of hydrothorax was established in 89 cases by X-ray examination, and in 20 of the remaining 47 cases the clinical diagnosis was confirmed by

a. *b.*

FIG. 1.—(*a*) Routine radiograph showing left hydrothorax. (*b*) Orthodiagram after inflation of stomach with gas, showing true size of effusion and depression of diaphragm. From a woman aged 45, with hypertension and left heart failure.

paracentesis or at necropsy. Stengel (1901) reported hydrothorax in 17 of 100 cases of heart failure, and Barié (1902) found "cardiac pleurisy" (presumably unilateral) in 10 per cent of 126 cases. These figures were based on clinical diagnosis or paracentesis, whereas ours were based mainly on radiological diagnosis which allows the inclusion of many small effusions. The frequency of hydrothorax in a series of patients with heart failure will of course increase the longer they are kept under observation, so that actual figures have little significance.

The incidence and distribution of hydrothorax in the different types of heart disease are shown in Table I.

TABLE I

DISTRIBUTION OF HYDROTHORAX IN DIFFERENT TYPES OF HEART DISEASE

Type of Heart Disease	Total Cases of Failure	Hydrothorax			
		Right	Left	Bilateral	Total
Hypertensive	136	16	21	8	45
Rheumatic	117	32	11	7	50
Arteriosclerotic ..	57	10	4	3	17
Thyrotoxic	27	7	3	5	15
Syphilitic	16	3	3	2	8
Myxœdematous ..	2	0	0	1	1
Emphysematous ..	1	0	0	0	0
TOTAL	356	68	42	26	136

Hydrothorax (10 oz. or more) occurred in 45 (41·3 per cent) of the 109 necropsies. This agrees closely with the post-mortem figures of Steele (1896), who found hydrothorax in 75 (43.2 per cent) of the 173 cases of failure, and of Cabot (1926) who found it in 79 (43·9 per cent) of 180 cases. The higher incidence of hydrothorax in post-mortem statistics is explained by the fact that they relate to a more advanced stage of heart failure than do clinical statistics.

FIG. 2.—Radiograph showing chronic left hydrothorax depressing diaphragm, from a woman aged 40 with chronic hypertensive heart failure; the left chest was aspirated fourteen times. Necropsy showed no lesion of left lung.

Distribution of Hydrothorax

In our 136 cases, hydrothorax was right-sided in 68, left-sided in 42, and bilateral in 26; included are 11 cases of interlobar hydrothorax, 9 right and 2 left. These figures give the site of hydrothorax when first recognized; an effusion at first unilateral occasionally became bilateral. In the 45 post-mortem cases, hydrothorax was right-sided in 11, left-sided in 9, and bilateral in 25.

The distribution of hydrothorax previously reported is given for comparison in Tables II and III.

TABLE II

DISTRIBUTION OF HYDROTHORAX IN CLINICAL STATISTICS

Author	Cases of Hydrothorax	Right	Left	Bilateral
Steele	27	11	5	11
Stengel	17	5	3	9
Forgeot	25	13	7	5
Lickint	60	23	1	36
Lord	30	16	6	8
Joly	82	40	6	36
TOTAL ..	241	108	28	105
Present Series ..	136	68	42	26

TABLE III

DISTRIBUTION OF HYDROTHORAX IN POST-MORTEM STATISTICS

Author	Cases of *Hydrothorax*	Right	Left	Bilateral
Steele	75	10	3	62
Cabot	76	14	10	52
TOTAL ..	151	24	13	114
Present Series ..	45	11	9	25

In comparison with previous records, ours show a high incidence of unilateral hydrothorax, and this requires explanation. We believe that pleural transudation often starts on one side of the chest before the other and that hydrothorax is commonly unilateral in its early stage. In response to treatment this process is reversed, and a bilateral hydrothorax disappears first on one side and then on the other. Our figures are based largely on radiological diagnosis in out-patients and therefore apply especially to the early and unilateral stage of hydrothorax. Post-mortem figures, on the other hand, relate to the terminal stages of heart failure and therefore show a relatively high incidence of bilateral hydrothorax.

In the clinical statistics tabulated, the average ratio of right- to left-sided effusions is only 3·8 to 1, and in the pathological statistics 2 to 1, which scarcely justifies the sweeping statements as to the predominance of right-sided hydrothorax found in most text-books. In our series based on radiological and clinical findings the average ratio of right- to left-sided effusions was 1·6 to 1 and in the pathological series 1·2 to 1. If our figures are combined with those quoted, both clinical and pathological, we find that, in 573 cases, hydrothorax was right-sided in 211, left-sided in 92, and bilateral in 270, giving a ratio of right- to left-sided effusion of just over 2 to 1.

Our series contains a far higher proportion of left-sided effusions than has generally been reported, but so do post-mortem statistics. As already stated,

many of the cases included in this analysis were encountered in the course of an investigation of the pulmonary stasis of left heart failure, in which, as we shall show, hydrothorax is usually left-sided. Admittedly this may have influenced our figures, but, even so, we believe that clinical observation has tended to exaggerate the preponderance of right hydrothorax, possibly because dullness due to elevation of the liver has either been mistaken for fluid or has caused a small left hydrothorax to be overlooked.

Distribution of Hydrothorax in Different Kinds of Heart Disease

It will be observed from Table I that in hypertensive heart failure left hydrothorax is appreciably more frequent than right, while in rheumatic heart disease right hydrothorax is thrice as frequent as left. The rheumatic group, consisting mainly of mitral stenosis, represents a predominantly right heart failure and hypertension a predominantly left heart failure. Before considering the significance of this relationship, we may note the influence of the heart rhythm (see Table IV).

TABLE IV

DISTRIBUTION OF HYDROTHORAX IN RELATION TO HEART RHYTHM

Rhythm	Hydrothorax			
	Right	Left	Bilateral	Total
Normal rhythm	25	30	16	71
Auricular fibrillation ..	43	12	10	65

In failure with normal rhythm left hydrothorax is rather more frequent than right, but in failure with fibrillation right hydrothorax is almost four times as frequent as left. The influence of rhythm is partly explained by the fact that normal rhythm is common in hypertensive failure and fibrillation in rheumatic failure, but not entirely, since the effect of rhythm still holds in certain ætiological groups (Table V).

TABLE V

DISTRIBUTION OF HYDROTHORAX IN NORMAL RHYTHM AND FIBRILLATION

Heart Lesion	Rhythm	Hydrothorax	
		Right	Left
Hypertension ..	Normal	10	19
	Fibrillation	6	2
Rheumatic disease	Normal	7	5
	Fibrillation	26	6
Aortic disease ..	Normal	5	8
	Fibrillation	7	2

Thus in hypertension and aortic disease, left hydrothorax predominates with normal rhythm and right hydrothorax with fibrillation. Similarly, in the rheumatic group, the incidence of left hydrothorax is higher in cases with normal rhythm than in those with fibrillation. The significance of this is discussed later.

Hydrothorax in Left Heart Failure

Hydrothorax in the absence of œdema has long been recognized, but that it may be part of the pulmonary congestion of left ventricular failure is not yet generally appreciated. In a previous publication (Bedford, 1939) it has been shown that hydrothorax may follow attacks of pulmonary œdema and that it may occur in hypertension, coronary occlusion, and syphilitic heart disease in the absence of or before signs of systemic congestion.

Our present series includes 24 cases of left heart failure with hydrothorax: in 9 the congestion remained confined to the lungs, and in the remainder hydrothorax preceded appreciable signs of systemic congestion. The hydrothorax was left-sided in 20 cases, right-sided in 2, and bilateral in 2. In a series of 154 cases of left ventricular failure Bedford observed hydrothorax in 38: it was left-sided in 18, right-sided in 9, and bilateral in 11; three cases had interlobar effusions. Normal rhythm was present in all cases. Thus hydrothorax in left heart failure has a definite predilection for the left side of the chest (see Figs. 1, 2, 3, & 5). The following cases are briefly quoted as examples of left heart failure with hydrothorax and pulmonary œdema.

Case 1. *Hypertension, coronary occlusion, paroxysmal dyspnœa, left hydrothorax*

Male, aged 64, first seen 23.5.35.

History. Coronary thrombosis three years previously, since which he had been liable to anginal pain on effort. Severe anginal pain at rest five weeks ago, followed by nocturnal dyspnœa and pulmonary œdema.

Examination. Pulse 90, regular. Arteries thickened. Blood pressure 195/115 mm. Apex-beat displaced to left, systolic murmur at apex. No œdema, cervical veins not engorged, liver not enlarged. Râles at both lung bases and dullness at left base. X-ray: pulmonary congestion and left hydrothorax. Cardiogram: inversion of T_2 and T_3. Treated by digitalis and salyrgan, and by aspiration of left chest. He recovered and went abroad, but died in November 1936.

Case 2. *Hypertension, paroxysmal dyspnœa, bilateral hydrothorax*

Male, aged 39, first seen 23.8.35.

History. Hypertension recognized for several years. For 9 months subject to paroxysms of nocturnal dyspnœa, recently severe, with blood-stained expectoration.

Examination. Regular pulse. Arteries thickened. Blood pressure 205/160 mm., marked alternation. Slight enlargement of heart to left; gallop rhythm at apex. Cervical veins not distended; no œdema; liver edge just palpable. Râles over both lungs and dullness at left base. X-ray: a large left and a smaller right hydrothorax. Cardiogram: left axis deviation, QRS splintered, T_1 negative. Treated by digitalis and salyrgan, and aspiration of left chest. Lungs became dry and hydrothorax cleared completely; he returned to work for six months, after which pulmonary congestion recurred, and he died in March 1936.

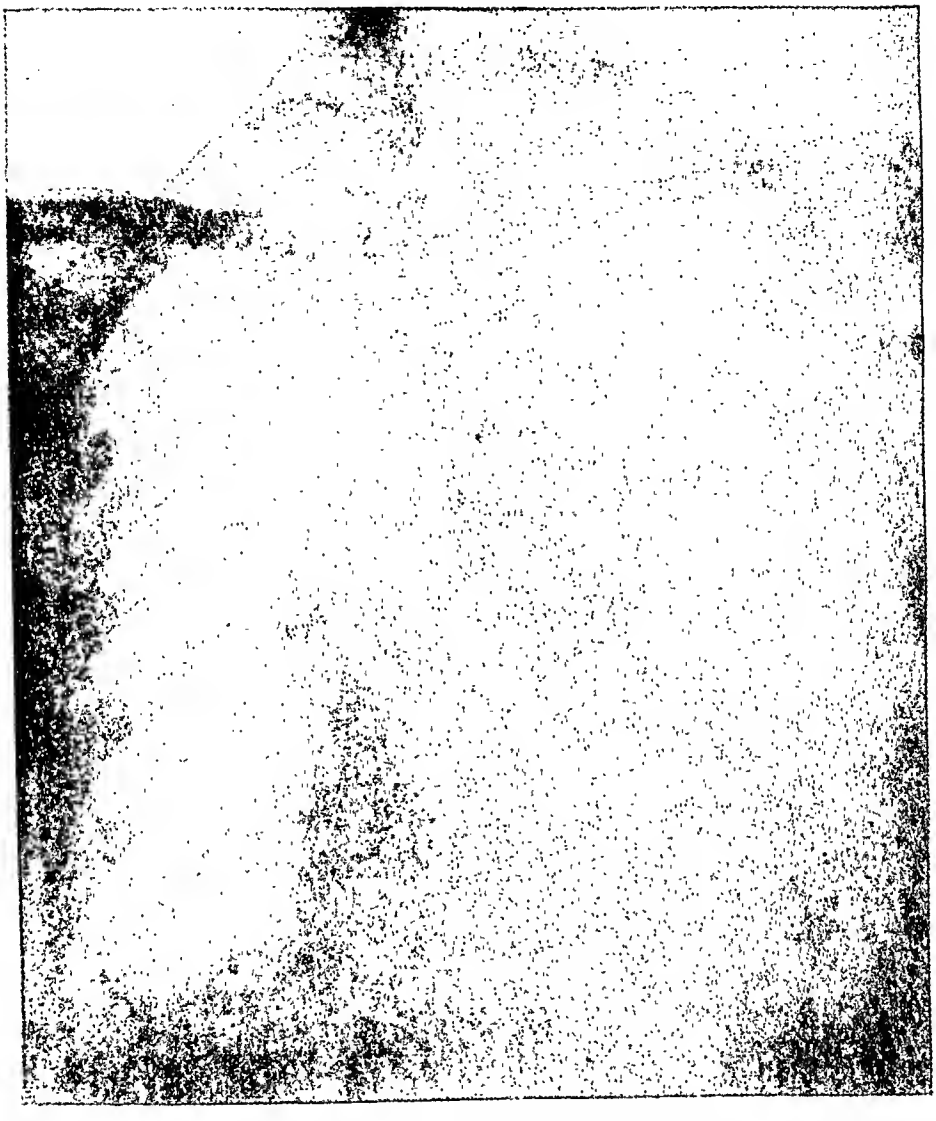

FIG. 3.—Radiograph showing left hydrothorax in a man aged 44, with hypertension and paroxysmal dyspnœa.

Case 3. *Hypertension, paroxysmal dyspnœa, left hydrothorax*

Male, aged 53, first seen 3.5.37.

History. Paroxysmal dyspnœa and nocturnal cough for 4 months, treated as bronchitis.

Examination. Pulse 128, regular. Arteries thickened. Blood pressure 170/110 mm. Slight pulsus alternans. Gallop rhythm at apex. No œdema; cervical veins not distended; liver palpable. Râles at both lung bases and dullness at left base. X-ray: pulmonary congestion and left hydrothorax; moderate cardiac enlargement. Cardiogram: normal rhythm, QRS splintered and T_1 negative. W.R. negative. Venous pressure, 10 cm. Arm to tongue circulation time (decholin), 28 secs. Treated with digitalis and salyrgan, the hydrothorax cleared up while in hospital.

Case 4. *Aortic incompetence, probably syphilitic, paroxysmal dyspnœa, hydrothorax*

Male, aged 60, admitted to hospital 22.7.38.

History. No rheumatic fever or chorea. For 7 months subject to attacks of

nocturnal dyspnœa with cough, wheezing, and frothy expectoration. Occasional sternal pain unrelated to effort.

Examination. Pulse regular, collapsing. Blood pressure 140/50 mm. Heart enlarged to left; aortic diastolic murmur. No œdema, no distension of cervical veins, liver not enlarged. Dullness and râles at left lung base. X-ray : dilated ascending aorta, right interlobar and left basal hydrothorax. Cardiogram : left axis deviation, QRS splintered, T_1 and T_2 negative. W.R. negative. He improved with treatment and left hospital, but died suddenly in December 1938.

Obliterative Pleurisy in Relation to Hydrothorax

In the 109 necropsies of heart failure that were analysed and in the 23 necropsies on our own cases, making 132 in all, complete obliteration of one or both pleural cavities occurred nine times; in seven the left pleural sac was obliterated, in one the right, and in one both sides. In five cases there was a contralateral hydrothorax, in the others none. Thus, obliterative pleurisy does occasionally explain a unilateral hydrothorax, though rarely in our cases a left-sided one. Pleural adhesions of some degree were of course common, and often involved the same side as the effusion. Where hydrothorax was recent there was usually little pleural change, but where it was chronic the pleura was sometimes much thickened, and in several cases there was atelectatic bronchiectasis of the lung on the affected side.

Pulmonary Infarction in Relation to Hydrothorax

In our 356 cases of heart failure, pulmonary infarction was recognized at some period in 46: 33 of these also had hydrothorax, but in only 13 of these could the hydrothorax be regarded as the sequel of infarction; 8 were right-sided and 5 left-sided effusions. In the remainder these two conditions seemed to be unrelated, either because hydrothorax preceded the infarct, or because the two occurred at different periods; in three cases the infarct and the hydrothorax were on the opposite sides.

Thus, as far as clinical observation goes, hydrothorax could only be attributed to infarction in 13 of 136 cases. Necropsies were obtained in 23 cases, in 9 of which there were lung infarcts, 5 on the right side, 3 on the left, and 1 bilateral. Hydrothorax was present in 8 of these 9 cases; in 4 it was bilateral, and in 4 unilateral and on the same side as the infarct. In the 109 post-mortem records analysed, lung infarcts were recorded in 42 cases, of which 20 also had hydrothorax.

It is difficult to draw any precise conclusions as to the rôle of pulmonary infarction in the causation of hydrothorax. In the terminal stages of heart failure, they are frequently associated, but even so a causal relationship must not be assumed too readily, for hydrothorax may precede the infarct or may be bilateral when the infarct is unilateral. Furthermore, in the absence of heart failure, for example after surgical operations, infarction does not usually cause an appreciable pleural effusion. If, as we believe, hydrothorax is a sequel of pulmonary venous engorgement, then the presence of an infarct in addition is

not of much consequence, apart from causing some degree of inflammatory reaction in the pleural transudate.

The average hydrothorax recognized clinically is by no means a terminal event, for in half of our cases it cleared up completely within a few weeks or months in response to treatment, rarely leaving any residual signs, and there is no reason to believe that pulmonary infarction was at all common. Chronic hydrothorax, on the other hand, does appear often to be associated with an infarct.

Interlobar Hydrothorax

There were 11 cases of interlobar hydrothorax in this series, 9 right- and 2 left-sided. An anterior radiograph shows a sharply defined lemon-shaped shadow in the right lung field (Fig. 4), or a more diffuse mid-zone opacity. An oblique or lateral view may demonstrate the effusion better. At least 29 cases of interlobar hydrothorax have previously been reported (Stewart, 1928; Kiser,

FIG. 4.—Radiograph showing pulmonary congestion and right interlobar hydrothorax, from a man aged 67, shortly after coronary occlusion; no œdema or systemic congestion.

1929; Freedman, 1931; Steele, 1931; Austrian, 1932; Vessel, 1932; Stein and Schwedel, 1934; Shiflett, 1935), apparently all right-sided and usually situated between the upper and middle lobes.

The occurrence of interlobar hydrothorax is usually attributed to obliteration of the main pleural cavity by adhesions, and post-mortem confirmation of this has been recorded (Stewart, 1928). Such an explanation is not always applicable, as in five of our cases there was also an effusion in the main pleural cavity (Fig. 5). Stein and Schwedel suggest that there are two types of inter-

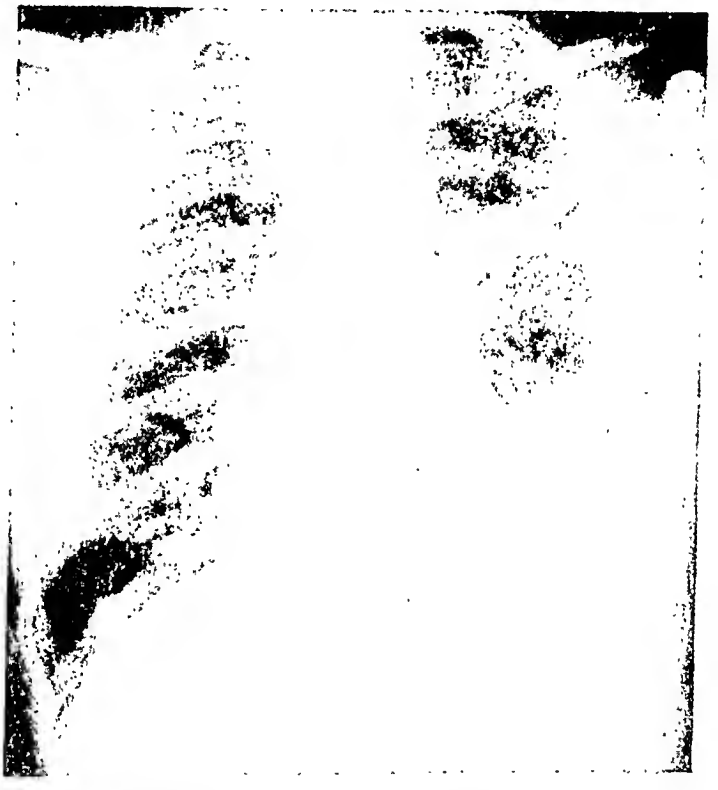

FIG. 5.—Radiograph showing left basal and small left interlobar hydrothorax, from a woman aged 47, with syphilitic aortitis and heart failure.

lobar hydrothorax, one a true encysted effusion, the other an indentation of the lung fissure, into which fluid seeps from the main pleural cavity; but this latter explanation seems to us unlikely. Zdansky (1929) points out that œdema and congestion of the lung in heart failure may be unevenly distributed and may be localized at the site of pleural thickening or pulmonary fibrosis. Radiographs often show an œdematous or thickened interlobar septum in heart failure, or even a thin lamellar effusion (Fig. 6), which represents the early stage of interlobar hydrothorax. The lung fissure has no connection with the systemic (azygos) venous system, and transudation at this site can only be explained in terms of pulmonary engorgement, a point of some significance in relation to the pathogenesis of hydrothorax.

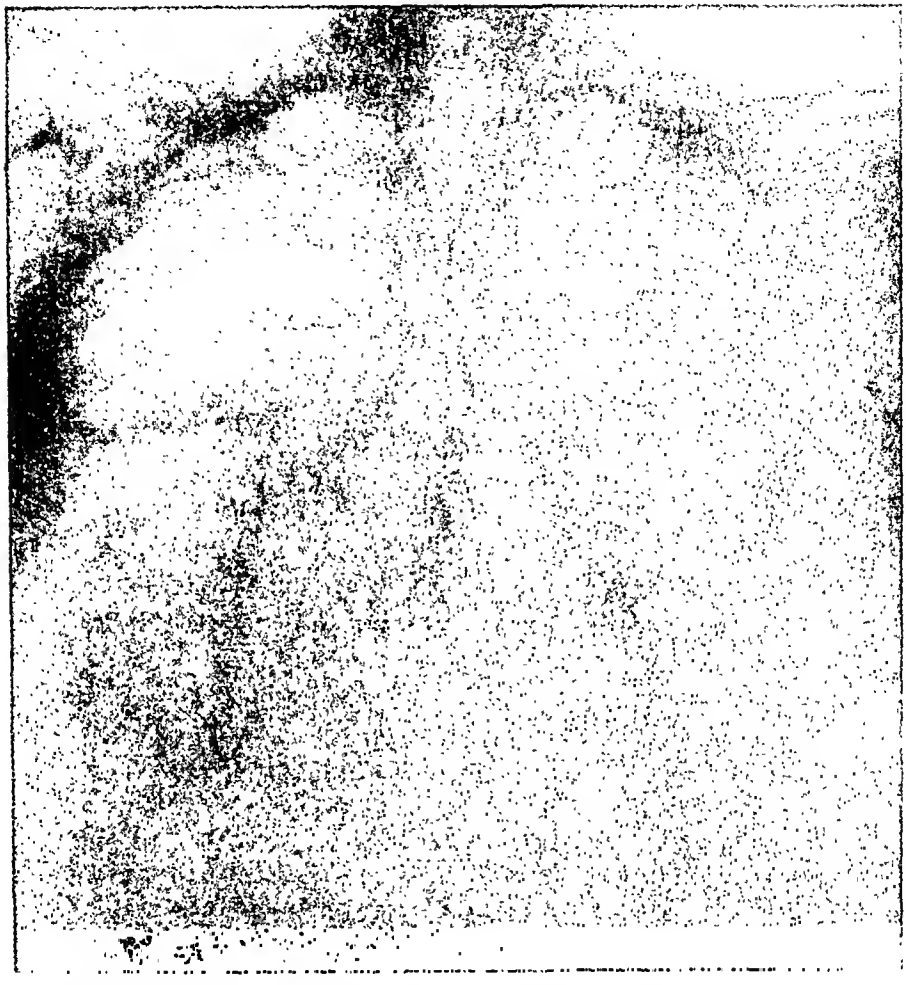

FIG. 6.—Radiograph showing pulmonary congestion and lamellar interlobar hydrothorax; right basal hydrothorax recently aspirated. From a man aged 62, with coronary occlusion, who was free from œdema and systemic congestion.

Analysis of Pleural Fluid

Fifty samples of pleural fluid from 27 cases were investigated in respect of specific gravity, cytology, and protein content. The specific gravity, determined by dropping the fluid into xylol chloroform mixtures of known specific gravity, varied between 1005 and 1034, the average being 1011·5; even in the same patient it varied by as much as 3 or 4 points at different times.

The cell content of the centrifuged deposit varied considerably in different specimens examined. Red cells were usually plentiful. Most obvious were endothelial cells, usually discrete, but quite often in plaques of 3 to 8 cells, and constituting up to 80 per cent of all cells in some samples. Lymphocytes were always present and sometimes predominated, ranging from 5 to 70 per cent. Polymorphs were usually scanty, but occasionally accounted for 70 per cent of all cells. The average cell content in 31 specimens was: lymphocyctes 45 per cent, endothelial cells 38 per cent, and polymorphs 17 per cent. A few specimens which showed a high polymorph count were from cases of pulmonary

infarction; more often polymorphs were absent or did not exceed 10 per cent. The usual cell formula corresponded to the "mixed type" of effusion, i.e. partly transudate, partly exudate.

The total protein ranged between 0·6 and 4·2 per cent, averaging 2·1 per cent; albumin 1·3 per cent, and globulin 0·7 per cent. Although the specific gravity and protein content of hydrothorax are usually lower than in a typical inflammatory effusion, there is considerable overlapping, and it seems doubtful if any sharp differentiation between transudate and exudate can often be made from analysis of the fluid alone. A high polymorph count and a frankly blood-stained fluid certainly suggest an infarct. Considering that pleural transudate is in contact with a chronically congested lung, it is not surprising to find that it often shows some degree of inflammatory reaction.

Clinical Course of Hydrothorax

Barié (1902) regarded true hydrothorax as a terminal event in heart failure, a view that was probably correct at the time. The advent of mercurial diuretics has contributed much towards a better outlook in these patients, and now they often survive the first appearance of hydrothorax by years. Salyrgan and similar preparations are of great value in dehydrating the lungs and pleuræ, and their use has largely obviated the need for aspiration.

In 70 of our patients the hydrothorax cleared up completely under observation, in half of them within a month and in all but 8 within nine months. In 21 cases the hydrothorax became chronic, persisting after other signs of failure had disappeared, and in 13 cases it was observed to persist for over a year (see Fig. 2), and once for 4 years. These patients were kept more or less free from œdema by digitalization and regular injections of salyrgan. In only 38 cases was hydrothorax a purely terminal event, appearing within a few months of death.

When hydrothorax cleared up within a few months, it left no residue, and X-rays showed normal clarity of the lung base and free diaphragmatic movements. In the more chronic forms, especially when associated with pulmonary infarction, there was usually evidence of pleural thickening and adhesions.

Pathogenesis

A raised venous pressure is accepted as an essential factor in the complex process of transudation of fluid into the tissues in heart failure. The pleural sacs have both a systemic and a pulmonary venous drainage. The parietal pleural veins are systemic and drain into the superior vena cava or its tributaries—mainly by the azygos veins, which are also connected with tributaries of the inferior vena cava via the lumbar veins. The capillary network of the visceral pleura, though its arterial supply is sometimes derived from the bronchial vessels, drains almost entirely into the pulmonary veins (Miller, 1937). Hydrothorax must therefore be considered in relation both to systemic and to pulmonary venous engorgement.

It has generally been assumed that hydrothorax is a manifestation of systemic venous stasis, and therefore *ipso facto* a transudate from the parietal pleura; yet there is scanty evidence to support such a view. West's case (West, 1909) of unilateral hydrothorax associated with azygos venous thrombosis, in a patient with nephritis, is usually cited, and the old azygos theory of Bacelli (1867) has so often been quoted in explanation of the supposed predominance of right-sided effusions that we have perhaps grown accustomed to thinking of hydrothorax in terms of the azygos veins. The factor of pulmonary venous stasis has certainly received inadequate consideration.

Bacelli postulated a constriction of the vena azygos major which was supposed to be stretched over the right lung root by downward traction of the dilated right heart. In fact, the diaphragm and heart ascend in heart failure, as shown by radiography, so that Bacelli's explanation must be discarded. Compression of the azygos vein by upward pressure of the dilated right auricle has also been suggested, but Fetterolf and Landis (1909) rejected this view, concluding that direct or indirect compression of the azygos by the heart was anatomically impossible. In view of the free anastamosis between the thoracic veins, compression of the vena azygos major seems to us an inadequate explanation of a right hydrothorax, and provides no explanation of a left hydrothorax. Pressure on the pulmonary veins in the right lung root was considered more likely on anatomical grounds by Fetterolf and Landis (1909) and by Steele (1896).

Fishberg (1937) has discussed the pathogenesis of hydrothorax in relation to left and right heart failure and his views deserve attention. He states that hydrothorax does not occur in isolated failure of the left heart and that pulmonary engorgement by itself cannot produce hydrothorax. He notes that hydrothorax may be absent in pure right heart failure with massive œdema and ascites, and concludes that both systemic and pulmonary stasis are requisite.

All who have investigated hydrothorax have observed that it may occur in the absence of œdema, yet if a raised systemic venous pressure were mainly responsible, as generally assumed, the pleura, with its alternative pulmonary venous drainage, should be the last rather than the first site of transudation. The only satisfactory explanation of hydrothorax without œdema, if we exclude pulmonary infarction, is in terms of pulmonary stasis due to left heart failure, in which, as we have shown, hydrothorax is not infrequent. If hydrothorax were mainly due to systemic stasis we should expect to find it early and constantly in conditions of right heart failure with severe venous engorgement, yet the reverse is the case. In tricuspid disease with failure, ascites is early and hydrothorax late, and the unusual clarity of the lung fields in radiographs has often been remarked (Fig. 7, p. 108). Similarly in heart failure due to atrial septal defect, in which extreme engorgement of the right heart is the rule, pulmonary œdema and hydrothorax are noticeably absent, but ascites is common (Bedford, Papp, and Parkinson, 1941). In mitral stenosis, though failure involves mainly the right heart, there is an obstruction distal to the lungs, so that pulmonary stasis occurs early and hydrothorax is common. To sum up, hydrothorax is found in the same conditions as pulmonary œdema, namely, in left heart failure,

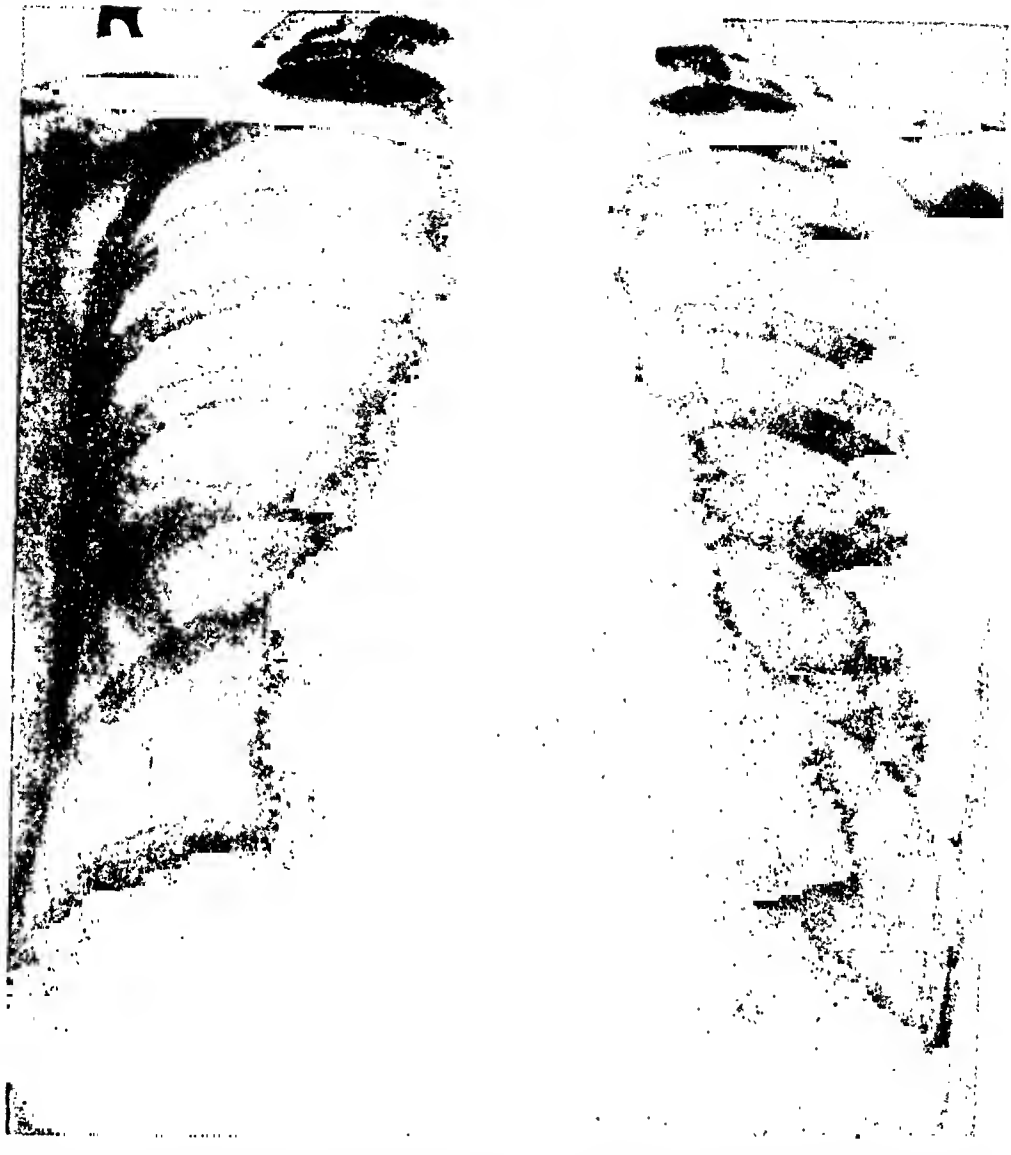

FIG. 7.—Radiograph trom case of rheumatic heart disease with longstanding tricuspid incompetence and heart failure with ascites and œdema. There is gross distension of vena cava and enlargement of right auricle, but lung bases are clear.

in combined left and right heart failure, and in mitral stenosis, and it is absent or late in pure right heart failure in which the lungs are spared. From this we may conclude that the essential factor in the production of hydrothorax is pulmonary engorgement, and that as long as the lungs are efficiently drained by the left heart, a rise in systemic venous pressure does not cause pleural transudation.

The occasional occurrence of interlobar hydrothorax supplies the proof that pleural transudation may occur quite independently of systemic congestion, for the interlobar pleura is not connected with the systemic veins. Similarly, when a unilateral effusion is determined by pulmonary infarction and heart failure, the visceral and not the parietal pleura is presumably the source of the fluid, which is probably a transudate with some degree of inflammatory reaction.

Lastly, the pulmonary origin of hydrothorax must appeal to all familiar with the radiology of heart failure. When a film of the chest, especially in a patient free from ascites and œdema, shows opacity around the lung roots, an œdematous right interlobar fissure, and basal pleural fluid (Fig. 6), the inference that these are alike manifestations of pulmonary congestion is difficult to avoid. Indeed, Zdansky (1929), in his classical account of the radiology of lung stasis, gives hydrothorax as the final stage.

We can now consider unilateral hydrothorax in terms of pulmonary as opposed to systemic congestion. We refer to those cases seen in the early and unilateral stage of pleural transudation, and not to the minority in which the site is determined by local conditions such as lung infarct or contralateral pleural obliteration.

We have shown that there is a definite relation between the site of the hydrothorax and the underlying heart condition, a conclusion previously reached by Steele. Pure left-sided heart failure, hypertension, and normal rhythm favour a left-sided hydrothorax, whereas failure with auricular fibrillation favours a right-sided one. Established auricular fibrillation is almost incompatible with pure left heart failure (Bedford, 1939), for it always involves systemic as well as pulmonary congestion, and is associated with some degree of right auricular dilatation. Thus it appears that enlargement of the left heart without right auricular dilatation, e.g. pure left heart failure, favours a left hydrothorax, and that dilatation of the right heart favours a right hydrothorax. It is not difficult to believe that enlargement of the left ventricle acts unfavourably on the circulation of the lower lobe of the left lung, either directly by compression, or indirectly by pressure on or displacement of the left pulmonary veins, the lower of which lies directly behind the left ventricle. Similarly, enlargement of the right auricle may affect the right lung root and favour a right-sided hydrothorax.

Anatomical differences between the two lungs have also to be considered, and Dock (1935) has studied their hydrostatic effect in relation to the pulmonary circulation, concluding that, in the usual bodily postures, gravity favours transudation into the right side of the chest. Many other explanations of right hydrothorax have been suggested, only one of which need be mentioned, namely, the effect of a swollen liver which may hinder the movements of the right diaphragm and so impair the circulation in the base of the right lung. Provided that the influence of cardiac enlargement is equally distributed between the two sides of the chest, it seems quite possible that anatomical differences may in some way favour right-sided pleural transudation.

Summary and Conclusions

Old and recent views on hydrothorax have been reviewed and its clinical and radiological diagnosis have been discussed.

Hydrothorax was observed at some stage in 136 (38·5 per cent) of 356 cases of congestive heart failure, diagnosis being mostly radiological, and in 45 (41·3 per cent) of 109 cases of failure examined post mortem. The hydrothorax was right-sided in 68 cases, left-sided in 42, and bilateral in 26; this included

11 interlobar effusions. Neither these nor previous statistics show right unilateral hydrothorax to be as predominant as generally supposed.

A definite relation was found between the site of the hydrothorax and the underlying heart condition. Hypertension, left heart failure, and normal rhythm favoured a left hydrothorax; mitral stenosis, combined right and left heart failure, and auricular fibrillation favoured a right hydrothorax. Clinical hydrothorax, which clears up rapidly with treatment, can rarely be attributed to pulmonary infarction, but in the terminal stages of heart failure and at post-mortem examination infarction is often an associated condition.

Hydrothorax is not uncommon in left heart failure, when it is a complication of pulmonary congestion. This explains its occurrence without œdema. In pure right heart failure ascites without hydrothorax is the rule.

The pleural fluid in hydrothorax may show some degree of inflammatory reaction, probably due to its contact with chronically congested lungs, and no sharp division between transudate and exudate (cardiac pleurisy) can usually be made.

In response to treatment by mercurial diuretics, hydrothorax often clears up completely within a few weeks or months, leaving no residue; but occasionally it becomes chronic and persists for a year or longer.

The pathogenesis of hydrothorax has been discussed and reasons given for regarding it as related to pulmonary rather than systemic venous engorgement, and as a transudate from the visceral rather than the parietal pleura. Unilateral and interlobar hydrothorax can better be explained in terms of pulmonary than of systemic stasis.

We are much indebted to hospital colleagues, especially Dr. G. E. S. Ward, for permission to follow up cases admitted under their care, and to Professor James McIntosh for laboratory facilities and for permission to analyse the post-mortem records of the Bland-Sutton Institute of Pathology. One of us (J. L. L.) has to thank the Medical Research Council for a whole-time grant during a part of this investigation.

REFERENCES

Austrian, C. R. (1932). *Libman Anniversary Volumes*, New York, **1**, 101.
Bacelli, G. (1867). *Patologia del Cuore e dell'Aorta*, Rome.
Barié, R. (1912). *Traité pratique des Maladies du Coeur et de l'Aorte*, 3rd edit., Paris.
—— (1902). *Semaine Méd.*, **22**, 25.
Beaufumé (1907). *Thèse de Paris*, No. 258.
Bedford, D. E. (1939). *Lancet*, **1**, 1303.
Bedford, D. E., Papp, C., and Parkinson, J. (1941), *British Heart J.*, **3**, 37.
Bucquoy (1882). *France Méd.*, cited by Barié.
Cabot, R. C. (1926). *Facts on the Heart*, Philad.
Comte, J. B. (1882). *De l'Hydropsie de Poitrine et des Palpitations du Coeur*, 2nd edit., Paris.
Corvisart, J. N. (1818). *Essai sur les Maladies et les Lésions organiques du Coeur*, 3rd edit., Paris.
Dock, W. (1935). *Amer. Heart J.*, **10**, 1047.
Fetterolf, G., and Landis, H. R. M. (1909). *Amer. J. med. Sci.*, **138**, 712.
Fishberg, A. M. (1937). *Heart Failure*, London.
Forgeot (1885). *Thèse de Paris.*
Freedman, E. (1931). *Radiology*, **16**, 14.
Joly, F. (1935). *Thèse de Paris*, No. 679.
Kiser, E. F. (1929). *Amer. Heart J.*, **4**, 481.
Laennec, R. T. H. (1826). *Traité de l'Auscultation Médiate*, 2nd edit., Vol. II, Paris.
Lickint, F. (1928). *Med. Klin.*, **24**, 809.
Lord, F. T. (1927). *Osler's Modern Medicine*, Lond., Vol. IV, 272.
Lovibond, J. L. (1937). Thesis for degree of M.D. Cambridge.

Maclean, L. (1810). *On Hydrothorax*, Sudbury.
Miller, W. S. (1937). *The Lung*, London.
Morgagni, J. B. (1761). *De Sedibus et Causis Morborum.*
Rénon, L. (1905). *Bull. Méd.*, **19**, 453.
Robert, J. (1897). *Thése de Paris*, No. 106.
Roubier, C., and Thévenet (1906). *Gaz. d'Hôp.*, Paris, **79**, 1047.
Sergent, E. (1925). *Journ. de Méd. et Chir. Prat.*, Paris, 96, 201.
Scherf, D. (1936). *Klinik und Therapie der Herz Krankheiten, und der Gefässerkrankungen*, 3rd Auflage, Wien.
Shiflett, E. L. (1935). *Radiology*, **25**, 429.
Steele, J. D. (1896). *Univ. Med. Mag. Philadelph.*, **9**, 563.
—— (1904). *J. Amer. med. Ass.*, **43**, 927.
Steele, J. M. (1931). *Amer. Heart J.*, **7**, 212.
Stein, J. D., and Schwedel, J. B. (1934). *Amer. Heart J.*, **10**, 230.
Stengel, A. (1901). *Univ. Penn. M. Bull. Philad.*, **14**, 103.
Stewart, M. J. (1928). *Amer. Heart J.*, **4**, 227.
Vessel, H. (1932). *Med. J. & Record*, **135**, 576.
West, S. (1909). *Diseases of the Organs of Respiration*, 2nd edit., London.
Wintrich, M. A. (1854). *Virchows Handbuch der Spec. Path. u. Therapie*, Vol. V, Erlangen.
Zdansky, E. (1929). *Wien. Arch. f. inn. Med.*, **18**, 461.

A COMPARISON OF THE MERCURIAL DIURETICS USED IN HEART FAILURE

BY

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Digitalis is without equal in the treatment of heart failure in mitral stenosis with auricular fibrillation, though diuretics may also be needed. But when heart failure occurs with normal rhythm, as in hypertension, mercurial diuretics usually prove more successful than digitalis in increasing the urinary output, in lessening pulmonary congestion, and in relieving dyspnœa. Since the circumstances that demand the use of diuretics are known, it is necessary to learn which preparation is best to prescribe, in what form to give it, and how best to improve upon its own diuretic effect.

The object of this paper is to provide answers to these inquiries, and to continue the investigations carried out in the Cardiac Department of the London Hospital by Thomson (1937). It gives the results of a clinical trial in which selected mercurial preparations were administered in various ways after different methods of premedication.

THE INVESTIGATION DESCRIBED

Fifty patients with heart failure, 30 men and 20 women, were selected for this clinical trial. Hypertension was the cause of the failure in 28, mitral stenosis in 12, and other less common conditions in 10 cases. The need for mercurial diuretics was determined by finding evidence of fluid retention on clinical examination. In some patients with hypertensive heart failure, frank œdema could not be demonstrated, but the symptom of breathlessness and the X-ray appearance of pulmonary congestion gave proof of their suitability for this form of therapy. Each patient was admitted to hospital and confined to bed during the period of investigation. The fluid intake was recorded daily and it was usually restricted to 35 ounces. The daily urinary output was also recorded. For convenience in assessing the results of this investigation, we have referred to the excess of the daily output of urine over the fluid intake, both measured in ounces, as the *diuretic index*. Naturally this figure is less than zero in a patient in whom heart failure is progressing. If vomiting or diarrhœa occurred under observation this received due regard in the interpretation of results. In some of the patients, especially those with mitral stenosis and auricular fibrillation, digitalis had to be given, but its effects had become constant and standard

before a mercurial diuretic was introduced, so that the results remain strictly comparable throughout periods of continued digitalization. The effect of a diminished fluid intake and of rest upon the urinary output was also kept in mind when the diuretic value of any medicine was being decided. The following preparations were submitted for clinical trial: esidrone, mersalyl, neptal, novurit, and salyrgan. Sometimes it was possible to try every preparation after different forms of premedication in the same patient, but more often it was only feasible to compare in a single patient either the preparations or the adjuvants. The preparations were given by intravenous or intramuscular injection in a dose of 2 c.c. by mouth, and by rectal suppository in the case of two preparations. The effects of 307 injections were observed, 197 intravenously and 110 intramuscularly.

Results

An estimate of the diuretic property of drugs, based as it must be on a comparison of the quantity of urine passed following their administration in different patients, requires care in that there may be several variables. We have tried to eliminate these by making allowance for the extent of anasarca at the time each medicine was given; by comparing the diuretic effect of each drug, only when it had been given to the same patient following the same form of premedication; by varying the sequence with which the drugs were given, because the first diuretic response is usually greater than succeeding ones; and by taking into consideration the interval between each administration. The results are presented under three main headings, which deal with choice of preparations, method of administration, and premedication.

I. Choice of Preparation

Judgement of the relative diuretic power of esidrone (prepared by Ciba), mersalyl (B.P. 1936; the variety used in this investigation was prepared by British Drug Houses), neptal (prepared by May and Baker), and salyrgan (prepared by Bayer) was made by comparing the effects of intravenous injection only, following the same form of premedication.

These preparations, which all contain theophyllin as well as mercury, were tried in 15 patients to whom 30 grains (2 g.) of ammonium chloride had been given two hours before each injection. They were not given in the same rotation, so that if esidrone was used first in one patient it was given second in the next patient, and third and fourth in succeeding patients. Again, each preparation that was given first was repeated before the second preparation was tried. That this manœuvre was necessary was shown later when the diuresis produced by the first and second injections were compared in 27 patients: the first injection induced greater diuresis than the second in 22, and the average *diuretic index* for the 27 patients was 72 for the first injection and 49 for the second.

The actual diuresis induced in each of the 15 patients by the four preparations is shown in Table I, and an analysis of these results is given in Table II. From

these data it will be seen that neptal and esidrone proved more efficient than salyrgan and that this were more efficient than mersalyl.

TABLE I

DIURETIC INDEX (EXPRESSING IN OUNCES THE EXCESS OF THE DAILY URINARY OUTPUT OVER THE FLUID INTAKE) PRODUCED BY FOUR MERCURIAL PREPARATIONS GIVEN INTRAVENOUSLY

Case No.	Esidrone		Mersalyl		Neptal		Salyrgan	
	Same Day	Next Day	Same Day	Next Day	Same Day	Next Day	Same Day	Next Day
3	76	0	33	−13	58	−7	24	− 7
5	67	29	58	11	62	5	86	29
6	84	2	63	4	176	10	92	8
7	67	17	49	−20	52	− 5	57	3
8	16	44	37	10	45	26	52	5
10	55	18	55	8	83	−1	83	−4
11	34	−8	11	−9	41	−7	27	−4
12	58	35	69	40	26	32	76	50
13	85	5	39	−11	25	−5	24	0
16	43	5	39	− 19	51	−20	13	0
17	26	2	6	0	29	−6	73	−15
21	62	22	65	10	67	12	26	− 7
22	116	10	47	1	84	16	40	−22
23	48	1	49	12	57	5	70	−3
24	96	9	69	−6	64	−19	75	−17
Average diuretic index	62	9	46	1	61	2	54	1

TABLE II

RELATIVE DIURETIC POTENCY OF FOUR MERCURIAL PREPARATIONS. THE NUMERALS INDICATE THE POSITIONS GAINED BY EACH PREPARATION IN 15 PATIENTS

Preparation	Relative Potency			
	1st Place	2nd Place	3rd Place	4th Place
Esidrone	5	3	4	3
Mersalyl	0	3	7	5
Neptal	5	5	3	2
Salyrgan	5	4	1	5

II. METHOD OF ADMINISTRATION

Esidrone, mersalyl, neptal, and salyrgan were tried by intravenous and intramuscular injection. The diuretic effects of mersalyl, neptal, and salyrgan were also compared when given by mouth in tablet form. Novurit was tried as a rectal suppository and sometimes compared with salyrgan suppository. Naturally the diuresis produced by mercurial preparations when taken by mouth was not expected to equal that obtained by injection, so that the value of intramuscular and intravenous injections was compared first; and separately, the relative value of tablets given by mouth and of rectal suppositories.

Intravenous and Intramuscular Injection

The effects of intravenous and intramuscular injections were observed on 15 occasions, always with similar premedication. Each of the four mercurial salts was included in this trial, and esidrone was given both by intravenous and intramuscular injection in 3 patients, mersalyl in 2, neptal in 5, and salyrgan in 5. The results are shown in Table III. The intravenous method induced greater

TABLE III

THE DIURETIC INDEX (EXPRESSING IN OUNCES THE EXCESS OF THE DAILY URINARY OUTPUT OVER THE FLUID INTAKE) OF INTRAVENOUS AND INTRAMUSCULAR INJECTIONS OF FOUR MERCURIAL SALTS.

Case No.	Preparation	Intravenous Injection		Intramuscular Injection	
		Same Day	Next Day	Same Day	Next Day
3	Esidrone	76	0	57	14
4	Salyrgan	73	20	40	12
6	Neptal	176	10	119	1
7	Salyrgan	57	3	48	−8
8	Mersalyl	37	10	24	52
10	Neptal	83	−1	69	2
10	Salyrgan	83	−4	42	−6
12	Neptal	26	32	58	39
12	Salyrgan	76	50	28	38
18	Salyrgan	32	3	62	−11
21	Mersalyl	65	10	56	10
22	Esidrone	116	10	87	21
22	Neptal	84	16	38	−13
23	Neptal	57	5	47	0
24	Esidrone	96	9	62	−13
Average diuretic index		76	11	56	9

diuresis on 13 out of 15 occasions, and this applied to each preparation. In one of two patients where intramuscular injection proved more efficient than intravenous injection this predominant effect was constant during further trials (Fig. 1). The average *diuretic index* was 76 for the first day and 11 for the second day for the intravenous injection and 56 and 9 for the intramuscular injection. The intravenous method was favoured by patients because they experienced greater pain from intramuscular injections.

Oral and Rectal Administration

The diuretic effects of tablets of mersalyl, neptal, and salyrgan, when taken by mouth, were observed during 68 separate trials with the same premedication. All the tablets contained 0·08 g. of the mercurial salt and 0·04 g. of theophyllin. Five different methods of administering them were adopted. Thus, always two hours after 30 grains (2 g.) of ammonium chloride, the dose was 2, 4, 6, or 8 tablets as a single dose, or 2 tablets three times during the day. Six tablets (0·48 g.) and 4 tablets (0·32 g.) produced the best diuretic effect, and this was actually greater than that produced by 8 tablets (0·64 g.). Mersalyl produced

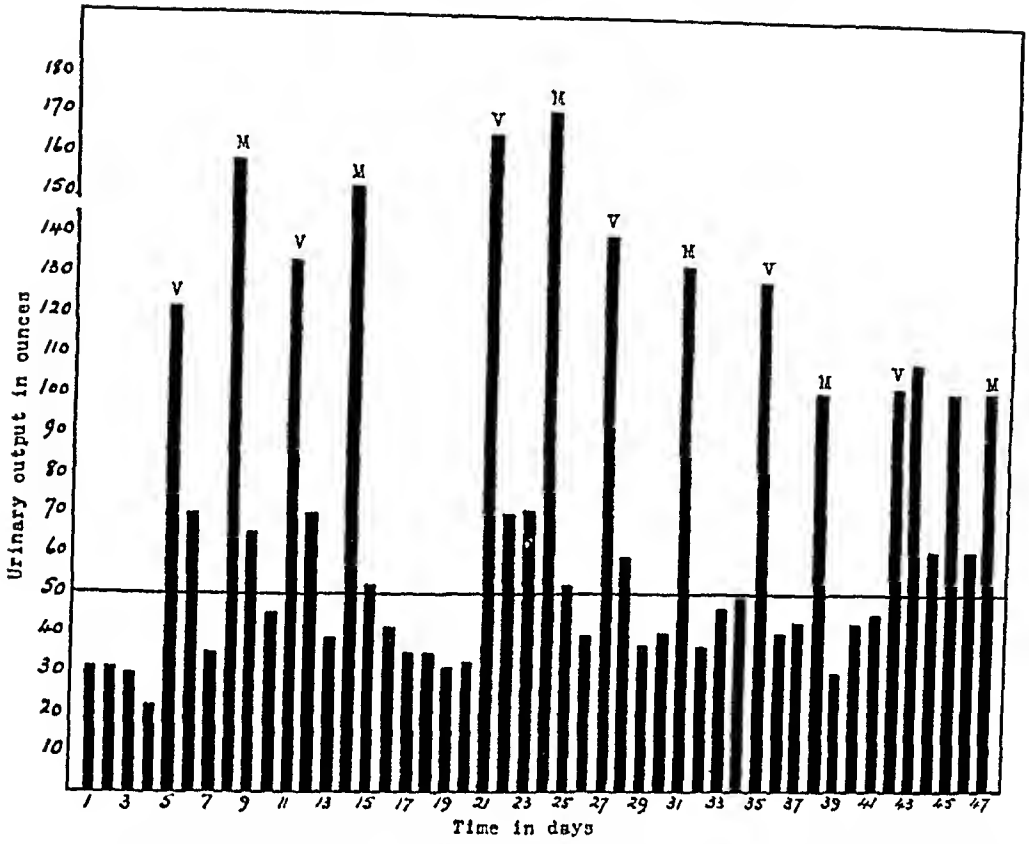

FIG. 1.—Comparison of the diuretic effects of intravenous and intramuscular injections of a mercurial salt in a patient with hypertensive heart failure. The daily fluid intake was kept constant at 50 ounces, and ammonium chloride (15 grains) was given three times daily. V, intravenous injection. M, intramuscular injection.
The superiority of intramuscular over intravenous injection was unusual.

satisfactory diuresis in 12 out of 19 trials and showed an average *diuretic index* of 19. Neptal tablets produced diuretic effects during each of 16 trials and the average *diuretic index* was 32. Salyrgan tablets were successful in 13 out of 23 trials and had a *diuretic index* of 17. Diarrhœa was often occasioned by the tablets when they were taken three times daily but seldom when given as a single dose. Vomiting sometimes resulted from the mechanical effects of swallowing many tablets, for this symptom did not recur when the tablets were repeated. Thus, neptal tablets produced diuresis in a greater measure than mersalyl and salyrgan tablets. As a result of these trials the makers have decided to double the strength of neptal tablets in order to facilitate the correct dose; three tablets now contain 0·48 g. of the mercurial salt and two tablets contain 0·32 g.

Novurit, and sometimes salyrgan, was administered as a rectal suppository in 21 patients. In 8 there was no diuretic response, and the *diuretic index* for all cases was 17. Novurit proved greatly superior to salyrgan suppository (Fig. 2). In 6 cases rectal irritation was produced. Premedication with euphyllin produced no better results than those obtained with ammonium chloride. When the diuretic effects of rectal and oral administration were compared the average *diuretic index* of 17 for the suppository was less than the

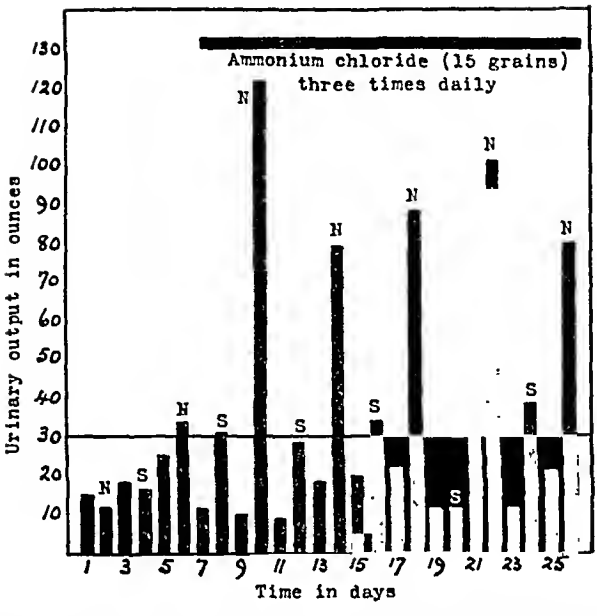

FIG. 2.—Comparing the diuresis produced by novurit and salyrgan suppositories, and showing the increased diuretic response following ammonium chloride in a patient with heart failure in mitral stenosis. The fluid intake was restricted to 30 ounces daily. N, novurit suppository. S, salyrgan suppository.

22 for all tablets, and much less than the 32 for neptal tablets. The discomfort commonly associated with a rectal suppository gave oral administration another advantage. The value of oral administration of mercurial salts in the treatment of hypertensive heart failure is further illustrated in Fig. 3, where it is compared with other methods.

III. PREMEDICATION

The extent to which different methods of premedication amplified the diuresis naturally induced by mercurial salts was another subject of inquiry. Eleven different methods were tried, and in all 507 observations were recorded. When the efficiency of each form of premedication was under test the same mercurial salt was given to each patient, so that when the adjuvant preparation was varied the conditions remained constant. The following preparations and methods were tried: urea (30 g.) two hours before the mercurial salt; euphyllin (0·4 g.) two hours before; digoxin (1 mg.) two hours before; vitamin C given continuously as 2 tablets of redoxon three times daily; and ammonium chloride (15 grains or 1 g.) three times daily for one, two, or three days, or in doses of 15, 45, or 60 grains two hours before. These results were compared with those reached without premedication. Neither digoxin nor vitamin C proved constantly effective in increasing the diuresis produced by a mercurial salt. The other methods were invariably successful and their relative efficiency is shown in Table IV. Ammonium chloride is supplied by Eli Lilly, and by Evans, Lescher, and Webb, in the form of compressed enteric chocolate-coated tablets containing 7·5 grains (0·5 g.). The unpleasant salty taste is thereby avoided and these

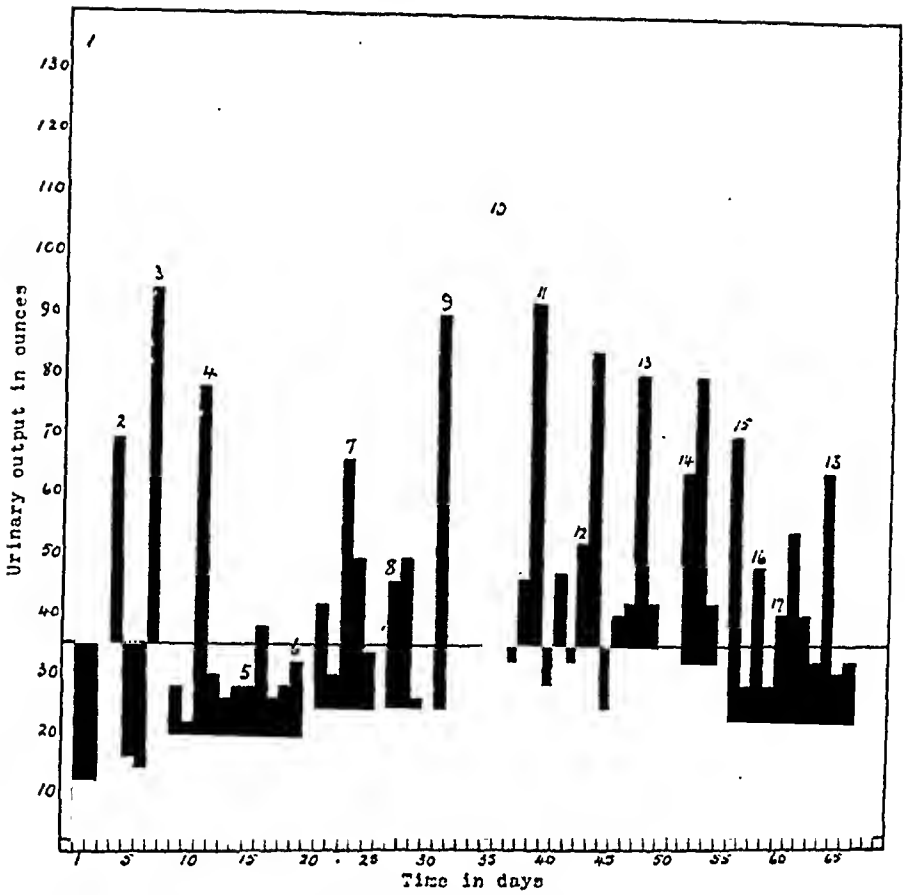

FIG. 3.—The diuresis produced by different mercurial preparations administered in different ways to a patient with hypertensive heart failure during ten weeks in hospital. Ammonium chloride (30 grains) was given two hours before each mercurial diuretic. The daily fluid intake was restricted to 35 ounces.

1. Salyrgan intravenously.
2. Mersalyl intravenously.
3. Neptal intravenously.
4. Esidrone intravenously.
5. Novurit suppository.
6. Novurit suppository.
7. Neptal, six tablets.
8. Salyrgan, six tablets.
9. Neptal, six tablets.
10. Neptal, eight tablets.
11. Neptal intravenously.
12. Neptal, two tablets, three times during one day.
13. Neptal, six tablets.
14. Neptal, two tablets, three times during one day.
15. Salyrgan, four tablets.
16. Mersalyl, four tablets.
17. Mersalyl, six tablets.
18. Neptal, six tablets.

TABLE IV

THE RELATIVE VALUE OF DIFFERENT METHODS OF PREMEDICATION IN AUGMENTING THE NATURAL DIURESIS PRODUCED BY A MERCURIAL PREPARATION

Order of Efficiency	Method of Premedication	Diuretic Index
1	Ammonium chloride (30 grains or 4 tablets) two hours before ..	69
2	Ammonium chloride (15 grains or 2 tablets) three times a day for three days	61
3	Ammonium chloride (15 grains or 2 tablets) three times a day for two days	58
4	Urea (30 g.) two hours before	57
5	Ammonium chloride (60 grains or 8 tablets) two hours before ..	54
6	Ammonium chloride (45 grains or 6 tablets) two hours before ..	53
7	Euphyllin (0·4 g.) two hours before	49
8	Ammonium chloride (15 grains or 2 tablets) three times a day for one day	39
9	Ammonium chloride (15 grains or 2 tablets) two hours before ..	39
10	No premedication	34

tablets were used whenever ammonium chloride was prescribed. From the table it will be seen that 4 tablets (30 grains or 2 g.) of ammonium chloride, taken by mouth two hours before the administration of a mercurial salt, proved the most efficient method of increasing its natural diuretic property.

Untoward Effects

No serious complications were encountered. Occasionally intramuscular injections, although given slowly, evoked local discomfort or even *pain* which lasted a variable time. *Vomiting* occurred sometimes when a number of tablets had to be taken, but this was not constant and during a second trial it might not recur. *Diarrhœa* usually resulted from the intake of a mercurial preparation by mouth three times daily. *Rectal irritation*, disagreeable, but never severe, affected one-third of the patients using a rectal suppository. *Uræmic symptoms* were seen once in a woman, aged 56, with hypertensive heart failure (Case 38). Slight albuminuria was present when she was admitted to hospital, but there was no evidence of renal failure and the blood urea was normal. Salyrgan was given every third day, alternately by intravenous and intramuscular injection, over a period of 50 days, during which ammonium chloride (15 grains three times daily) had been given continuously. On the fiftieth day the patient was taken ill with weakness, anorexia, vomiting, listlessness, drowsiness, and dryness of the mouth and tongue. Ammonium chloride and salyrgan were discontinued and the fluid intake was increased. Within five days the patient became free from symptoms. Over a period of fourteen days after stopping the drugs the following blood urea values were obtained: 178, 225, 115, 109, 90, and 60 mg. per 100 c.c. After three months, breathlessness returned and there was further need of treatment with mercurial diuretics; these were given following ammonium chloride premedication once a week during the following twelve months with freedom from symptoms of failure and without the advent of uræmic symptoms. As this single experience came to us early in the investigation the blood urea was estimated at least three times in the rest of the series. The first estimate was made before the investigation began, the second during the investigation, and the third towards the end. In none was the blood urea content raised significantly during treatment.

Conclusions

Certain mercurial diuretics were submitted to a clinical trial in 50 patients with heart failure, for the purpose of deciding their relative diuretic potency. The best method of administering them was also investigated, as well as the best means of augmenting their natural diuretic action. Esidrone, mersalyl, neptal, and salyrgan were given in 2 c.c. doses intravenously (197 times) and intramuscularly (110 times). Mersalyl, neptal, and salyrgan were tried orally in tablet form, and novurit and salyrgan were tested as a rectal suppository. Eleven methods of enhancing the diuretic effects of mercurial salts were also tested, and 507 observations were devoted to this problem. The results of this investigation are as follows:

1. Neptal and esidrone when given intravenously or intramuscularly pro-

duced the largest diuresis, rather larger than salyrgan and much larger than mersalyl.

2. The intravenous method almost always induced greater diuresis (average *diuretic index* of 76) than the intramuscular method (average *diuretic index* of 56).

3. Of the two rectal suppositories tried, novurit gave much better results than salyrgan.

4. Neptal tablets by mouth proved more efficient (average *diuretic index* of 32) than mersalyl tablets (average *diuretic index* of 19), salyrgan tablets, or novurit suppositories rectally (each with a *diuretic index* of 17). Ammonium chloride was always given in association.

5. Although the urinary output after oral administration of a mercurial salt was greatest when 0·48 g. (3 new tablets) of neptal were used, satisfactory diuresis was also produced by 0·32 g. (2 new tablets).

6. Thirty grains (2 g.) of ammonium chloride given two hours before the administration of a mercurial preparation proved to be the best form of pre-medication. Enteric chocolate-coated tablets, each containing 7·5 grains (0·5 g.), proved the most convenient form of dispensing ammonium chloride.

7. In a patient confined to bed with heart failure and especially with œdema, standard treatment would include the injection of a mercurial diuretic (2 c.c.) intravenously or intramuscularly every third day, preceded on each occasion by the administration of 4 tablets (30 grains or 2 g.) of ammonium chloride by mouth two hours before. During the ambulatory stage the patient should take neptal tablets (3 in all, or 0·48 g.), twice weekly in the *more severe case* and once a week in the *less severe case*, after the same premedication, and receive an intravenous or intramuscular injection (2 c.c.) at intervals according to need.

We wish to thank Dr. John Parkinson, Physician to the Cardiac Department of the London Hospital, for his helpful criticism of this paper. Dr. P. T. Savage joined in the investigation when he was House Physician to the Department. We acknowledge the able co-operation so loyally given to us by Sisters in charge of the wards. Mr. C. H. Sykes, Ph.C., Chief Pharmacist to the Hospital, has given us great assistance.

REFERENCE

Thomson, W. A. R. (1937). *Quart. J. Med.*, 30, 321.

COARCTATION OF THE AORTA WITH PATENT DUCTUS ARTERIOSUS

BY

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While serving in the R.A.M.C. at a military hospital, it has been our good fortune to see a considerable number of patients with congenital heart disease. One of these with coarctation of the aorta presented certain unusual features, notably patency of the ductus arteriosus. In themselves these two defects are not amongst the rarer developmental abnormalities of the cardiovascular system, but their combination in a diagnosis made during life appears to be rare enough to justify detailed consideration.

Evans (1933) stated that coarctation of the aorta was found in approximately one in every 1000 necropsies, while Blackford (1928) estimated the incidence as one in every 1550 necropsies.

Patency of the ductus arteriosus occurred in 262 of Abbott's (1936) series of 1000 cases of congenital cardiac defects; in 40 it was combined with pulmonary atresia or stenosis, in each instance being associated with a septal defect. In the same series of 1000 cases she described 178 examples of coarctation of the aorta, of which 105 belonged to the adult type; 70 were analysed in detail, and in only 6 of these was the ductus arteriosus patent.

Description of the Case

Our patient, aged 25, was the wife of a corporal. There was nothing of note in the family history. Both parents, her sisters, and two brothers were alive and well; her husband was in good health. She herself could remember no previous illness, apart from diphtheria at twelve years, when she was ill for six weeks. As a child she had made no complaint of breathlessness, and took part in all games when at school with enjoyment. Later she was employed as a shop assistant without incident. She was married at nineteen years and was evidently a most active housewife. A year later she became pregnant, and at the seventh month began to suffer for the first time from headache, nausea, and vomiting that was difficult to control. While no œdema was observed, albumin was present in the urine, and on the fifth day of severe symptoms the pregnancy was terminated. It should be noted that there was no history of convulsions. All symptoms disappeared in three days, but she was told she had "kidney trouble" and that another pregnancy would be strongly contra-indicated. This unfavourable prognosis apparently induced

an element of introspection and doubt as to her own well-being which led the patient to present herself at various hospitals for examination; however, little amiss seems to have been found. In September 1940 she was six weeks in hospital with a diagnosis of pyelitis. At this time there was some dysuria which continued to a lesser extent, but at no time had polyuria been noted.

She came under the care of one of us (J. G. G.) some four months later with a provisional diagnosis of chronic nephritis. She made no specific complaint apart from slight discomfort on micturition and lumbar pain when tired. However, she volunteered that she became breathless on exertion and that her lips occasionally turned blue, her nails becoming blue easily in cold weather. She also stated that her feet were always cold, although there was no history of chilblains or of intermittent claudication.

The patient was of small build and stature (height, 4 feet, 11 inches; weight, 91 pounds), and was somewhat pallid and wax-like in complexion. On admission to hospital there was no cyanosis or clubbing of the fingers, nor was there any evidence of dilated vessels in the thorax; there was, however, marked arterial pulsation at the root of the neck. Neither dyspnœa nor orthopnœa was noted. Physical examination of lungs, abdomen, and nervous system did not show any abnormality.

Cardiovascular System. The pulse rate was 70 per minute, the rhythm being regular; the force was good, but the pressure was higher at the left wrist than at the right. The vessels were not hardened to palpation. Pulsation could not be detected either in the abdominal aorta or in the great vessels of the lower limbs. Palpation showed the apex beat to be in the fifth left interspace, four inches from the mid-line. There was marked pulsation of both carotids, and also of the aorta in the episternal notch, but no tracheal tugging. Percussion did not elicit any obvious change in cardiac dulness. On auscultation at the apex three heart sounds were heard, the third following at a short interval after an apparent second sound. One inch internal to the apex beat systolic and diastolic murmurs were present, the heart sounds themselves being well heard and of good tone. At this point the third sound was not audible and the diastolic murmur partly obscured and followed the second sound. There was nothing to suggest the presence of a presystolic murmur. At the aortic cartilage and down the sternum to the xiphoid there was a systolic murmur, but the second sound was pure. Over the aorta and great vessels a systolic bruit was heard, and also in both interscapular areas, especially at the third and fourth left interspaces. In the second left interspace in front, about one and a half inches from the mid-line, a continuous machinery murmur of the water-wheel type was heard, being crescendo during systole and continuing throughout diastole. This murmur was also conducted up to the left clavicle. Throughout the period of observation there were considerable variations in the systolic blood pressure from day to day, but at first there was a constant difference of some 50 millimetres of mercury between the readings obtained in the two arms, the left being the higher. The readings in both upper limbs were greatly in excess of those in the legs, typical figures being: right arm, 175/90; left arm, 225/110; legs, 130 systolic.

On admission the urine showed a trace of albumin and contained a few polymorphs and coliform organisms. No casts were found. A urea concentration test gave a figure of 2·65 per cent at the second hour. The blood urea was 39 mg. per 100 c.c. Later the urine became normal. A gynæcological examination did not reveal any abnormality.

Blood examination: Hæmoglobin 82 per cent, red blood cells 4,700,000 per c.mm., white blood cells 11,200 per c.mm. Examination of blood films, including a differential count, did not reveal any abnormality. The Kahn test was negative. The blood sedimentation rate was well within normal limits.

Ophthalmic examination: The pupils were always moderately dilated and unequal, the degree of inequality varying from day to day; sometimes the one and sometimes the other was the more dilated. The reactions both to light and to convergence were sluggish. The fundi showed no evidence of arterial or venous pulsation or any other abnormality.

Radiological examination of the chest showed enlargement of the right ventricle and a prominent and pulsatile conus; the aortic knuckle was somewhat small (Fig. 1). Fig. 2, a similar view from one of our uncomplicated

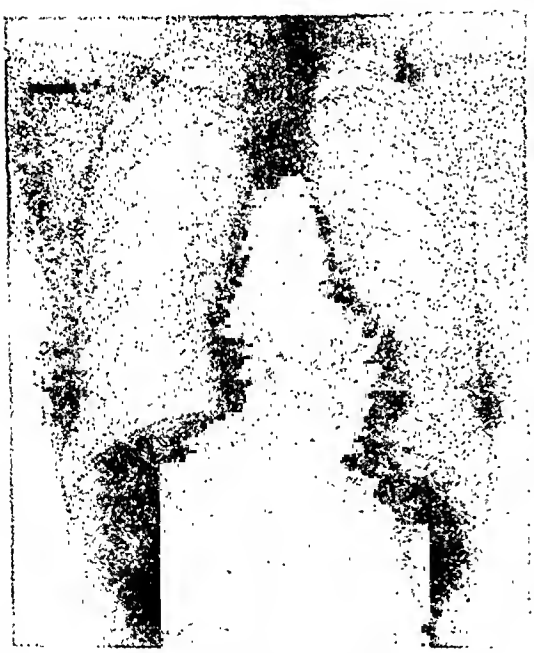


FIG. 1.—Antero-posterior view of our patient, at 2 metres, showing right-sided cardiac enlargement, and erosion of ribs.

FIG. 2.—Antero-posterior view, at 2 metres, of an uncomplicated case of patent ductus arteriosus.

cases of patent ductus arteriosus, a female aged 28 years, is included for comparison. Although oblique views of the subject of this paper revealed an apparently normal ascending and transverse aorta, the remainder of the arch could not be visualized. In the left (II) oblique position the aorta and its branches, as Lewis (1931) has described, seemed to rise as a column from the heart shadow up into the root of the neck.

Rösler's sign—erosion of ribs—was present. This is clearly seen in Figs. 1, an antero-posterior view taken at two metres, and in greater detail in Fig. 3. In

FIG. 3.—Left upper quadrant, showing erosion of ribs in detail.

FIG. 4.—Left (II) oblique view of our patient.

Fig. 4, a left (II) oblique view, the prominent pulmonary conus is well seen, but the descending arch of the aorta is not visualized.

An electrocardiogram, Fig. 5, shows changes in the ventricular complexes comparable with those described by Evans and Turnbull (1937), following the work of Wilson *et al.* (1934), as denoting right bundle branch block. This newer curve, which is said to be much commoner than the one standard for right bundle branch block, is characterized by a deep S wave as a component of a wide QRS complex in lead I (measuring 0·12 sec in this case), and also in lead II, by the QRS complex in lead III being directed downwards ; and by the T wave being upright in leads I and II and inverted in lead III. The changes seen in the sternal lead (Fig. 5) would seem to be in conformity with this diagnosis.

After three weeks' rest in bed the patient stated that she felt fitter in all respects. She had been afebrile throughout this period. The difference between the two radial pulses and the two brachial blood pressures became much less marked. The systolic pressure in the arms, however, remained considerably in excess of that in the legs, typical findings being : right arm, 205/120; left arm, 215/120; legs, 130 systolic.

DISCUSSION

This case presents many unusual features, both in the history and clinical findings. There had been no evidence of cardiac insufficiency until the patient's twentieth year, when she was a seven months primagravida. At that time the

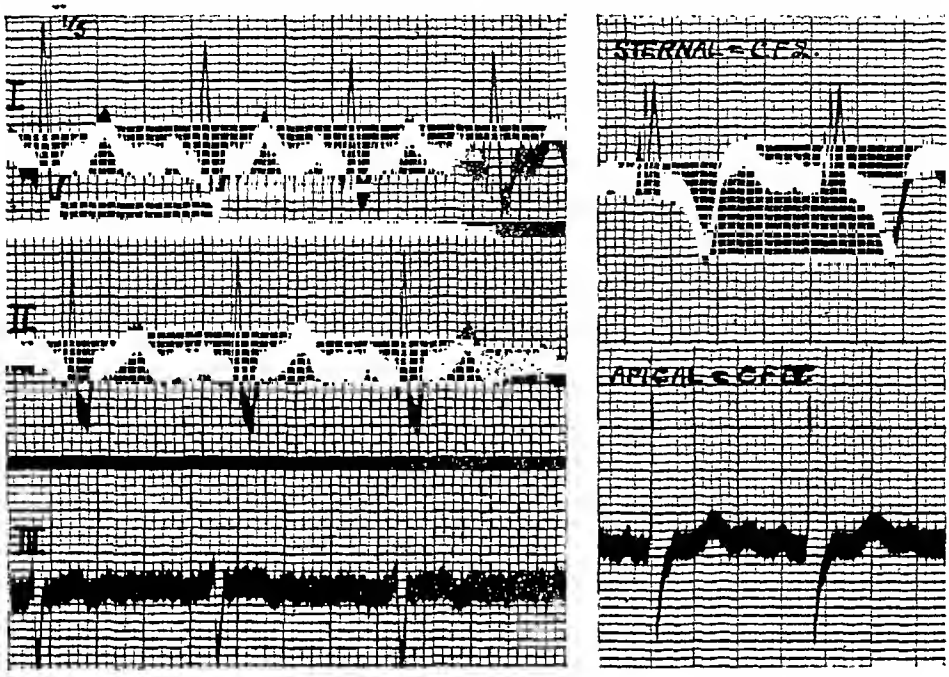


FIG. 5.—Electrocardiogram of the case described, showing a conduction defect comparable with the " newer " type of right bundle branch block.

development of headache, nausea, and vomiting, combined with the presence of albuminuria, were interpreted as being due to renal disease. In view of her subsequent history and the results of the present investigation (which *inter alia* show no evidence of impaired renal function but only of a mild urinary infection that responded to the simplest therapeutic measures) it seems reasonable to suggest an alternative explanation. Her symptoms may be interpreted as due to the development of chronic venous congestion through the late months of pregnancy overtaxing a circulation already hampered by a congenital cardiac defect. It is now suggested that consideration of the physical findings indicates a complex defect of which the several components are outlined.

(1) *Coarctation of the Aorta.* X-ray films taken at two metres showed an ascending aorta of normal size, with a rather undersized knuckle, while the remainder of the arch was not visualized. Moreover, Rösler's sign was present. In addition a loud systolic bruit was heard at the aortic cartilage and was conducted into the neck and to the interscapular area posteriorly. The blood pressure in either arm was markedly raised, and in great excess of that in the lower limbs. The gross difference in pressure between the two upper limbs noted on admission to hospital, presumably with a reduced cardiac reserve, when the left brachial exceeded the right by some 50 millimetres of mercury, is explainable by the coarctation being situated just distal to the entry of the patent ductus to the aorta, from which the great vessels may take an unusual origin.

(2) *Patency of the Ductus Arteriosus*, as instanced by the characteristic machinery murmur heard in the second left space and conducted up to the left clavicle. In this case the shunt was predominantly arterio-venous, the patient being free from cyanosis.

(3) *A Ventricular Septal Defect* is postulated on account of the well-marked and separate systolic and diastolic bruits heard inside the apex beat, and the bizarre cardiogram comparable with the Wilson type, now recognized as indicative of right bundle branch block. Radiological evidence indicated enlargement of the right ventricle and of the conus. In Abbott's analysed series of 110 cases of pulmonary stenosis there was a septal defect in 101. On the other hand, in 70 with aortic coarctation of the so-called adult-type there were only 7 instances.

Cowan and Ritchie (1935) point out that patency of the ductus arteriosus may be first recognized during an illness, or in later life on examination for military service or life assurance. We have noted 4 cases of this anomaly in one year in the out-patient department of a military hospital. Similarly, it is of interest to recall that 8 of Lewis's 9 patients with coarctation of the aorta were army pensioners. Evans has recognized six different types of coarctation of the aorta, according to the site of the constriction, the patency of the ductus arteriosus, and the state of the aorta proximal to the constriction. Under this classification our case would be placed in Type I. Among the 8 cases of this type that he described, only one had reached adult life, a man aged thirty years, in whom necropsy showed wide patency of the ductus with enlargement of the right heart. Where the coarctation occurs at its usual site—distal to the origin of the left subclavian—the radial pulses are equal. Various observers, including King (1937), Parker and Dry (1938), and Bayley and Holoubek (1940), have noted that the pulses may be unequal, the right being more forceful than the left, and have explained this by a coarctation at or above the origin of the left subclavian artery. In our case, however, the left pulse was more forceful than the right. In the limited review of the reported cases that we have been able to attempt under present conditions we have only noted two similar cases (King, 1926, and East, 1932). It is realized that the explanation of the physical findings which we have advanced is a purely hypothetical one, and that the final truth can only be revealed at necropsy.

Our grateful thanks are due to Dr. G. A. Allan for his criticism, and to Colonel D. F. Mackenzie, D.S.O., late R.A.M.C., and Colonel R. A. Lennie, T.D., late R.A.M.C., for permission to publish this case.

We have pleasure in acknowledging our indebtedness to Major W. C. Armstrong, R.A.M.C., Major E. G. Recordon, R.A.M.C., and Lieut. D. H. Cummack, R.A.M.C., for the gynæcological, ophthalmic, and radiological examinations, and to Mr. R. P. Danskin, of Edinburgh Royal Infirmary, who took the electrocardiogram.

References

Abbott, M. E. (1936). *Atlas of Congenital Cardiac Disease*, New York.
Bayley, R. H., and Holoubek, J. E. (1940). *Brit. Heart J.*, **2**, 208.
Blackford, L. M. (1928). *Arch. intern. Med.*, **41**, 702.
Cowan, J., and Ritchie, W. T. (1935). *Diseases of the Heart*, London, p. 479.
East, T. (1932). *Proc. Roy. Soc. Med.*, **25**, 797.
Evans, W. (1933). *Quart. J. Med.*, N.S., **2**, 1.
—— and Turnbull, H. M. (1937). *Lancet*, **2**, 1127.
King, J. T. (1926). *Arch. intern. Med.*, **38**, 69.
—— (1937). *Ann. intern. Med.*, **10**, 1802.
Lewis, T. (1931–3). *Heart*, **16**, 205.
Parker, R. L., and Dry, T. J. (1938). *Amer. Heart J.*, **15**, 739.
Wilson, F. N., Johnston, F. D., Hill, I. G. W., MacLeod, A. G., and Barker, P. S. (1934). *Ibid.*, 9, 459.

A FATAL CASE OF MYOCARDIAL CONTUSION

BY

HUGH BARBER AND G. R. OSBORN

From the Derbyshire Royal Infirmary

Received March 18, 1941

The notes of this case are of interest, because a healthy young man died as the result of an uncomplicated myocardial contusion in the region of the left ventricle. The heart muscle was not ruptured, and there was no blood in the pericardial sac. Death was due to acute pulmonary œdema.

CASE HISTORY

On February 18, 1941, a sailor 22 years of age was found lying face downwards in the road, with the mark of a large motor-tyre across the left side of his back. It appears that one wheel of a loaded five-ton trailer passed over him. This was about midnight. He was admitted to the Derbyshire Royal Infirmary, where he died about four hours later.

The clinical evidence comes from an experienced house surgeon. The patient was semi-conscious and smelt of alcohol. There were some abrasions on the legs. There were no signs of head or chest injury. The heart and lungs were apparently normal. The problem appeared to be one of concussion, in a man who had taken alcohol. At 1.30 a.m. the pulse rate was 100 and regular; the respirations were 30 to the minute; and there was no obvious distress. At 2.0 there was no change, but by 2.30 the respirations were 40 and at 3.30 the pulse rate 120. About this time he began to bring up large quantities of frothy fluid and he died at 4 a.m.

POST-MORTEM EXAMINATION

The body was that of a strong man of 22 years. He was of average build and 5 feet 8 inches tall.

Externally there were multiple bruises and abrasions over both legs, the right iliac fossa, the nose, and the chin. There was an incomplete fracture of the second left rib in the mid-axillary line, and bruising extended for about an inch all around this, but the pleura was not torn. No other bones were fractured.

The mouth, trachea, and bronchi were filled with blood-stained froth. There were fairly generalized old pleural adhesions on both sides; no hæmothorax was present. The lungs showed general acute œdema, and blood-stained fluid poured from the cut surfaces. No chronic lung disease was

found, and there were no large hæmorrhagic lesions similar to those seen in pulmonary concussion.

The pericardial sac was normal. Pericardial fluid was clear and only slightly increased.

The heart weighed 11 ounces. It was of normal size and shape. There was well-marked bruising of the left ventricle: the distribution of this is shown in the drawings. It was most severe over the whole lateral aspect (margo obtusus) and anteriorly near the apex. On section the bruising was seen to extend from the pericardial surface to a variable depth, this being mostly under half the thickness of the muscle ; in one place only, about the origin of the anterior papillary muscle, did it extend through the muscle and appear beneath the endocardium. The endocardium and valves were undamaged. Bruising was present about the bifurcation of the left coronary artery and followed the circumflex branch for about an inch. The right ventricle was normal, except for very slight bruising near the base. The two auricles and the great vessels were undamaged.

The skull, meninges, and brain were normal.

There was no blood in the peritoneal cavity, though there was bruising of the transverse colon and a small tear of the transverse mesocolon. The other abdominal organs were all normal.

The strong smell of alcohol when he was admitted was due to a bottle breaking in his clothing. The alcohol in the blood was only 85 mg. per 100 c.c.

Microscopically, many small groups of muscle fibres were seen to be ruptured, and this was most marked close to the pericardium. Hæmorrhage had taken place about these small ruptures and beneath the pericardium. The heart muscle otherwise showed a normal structure.

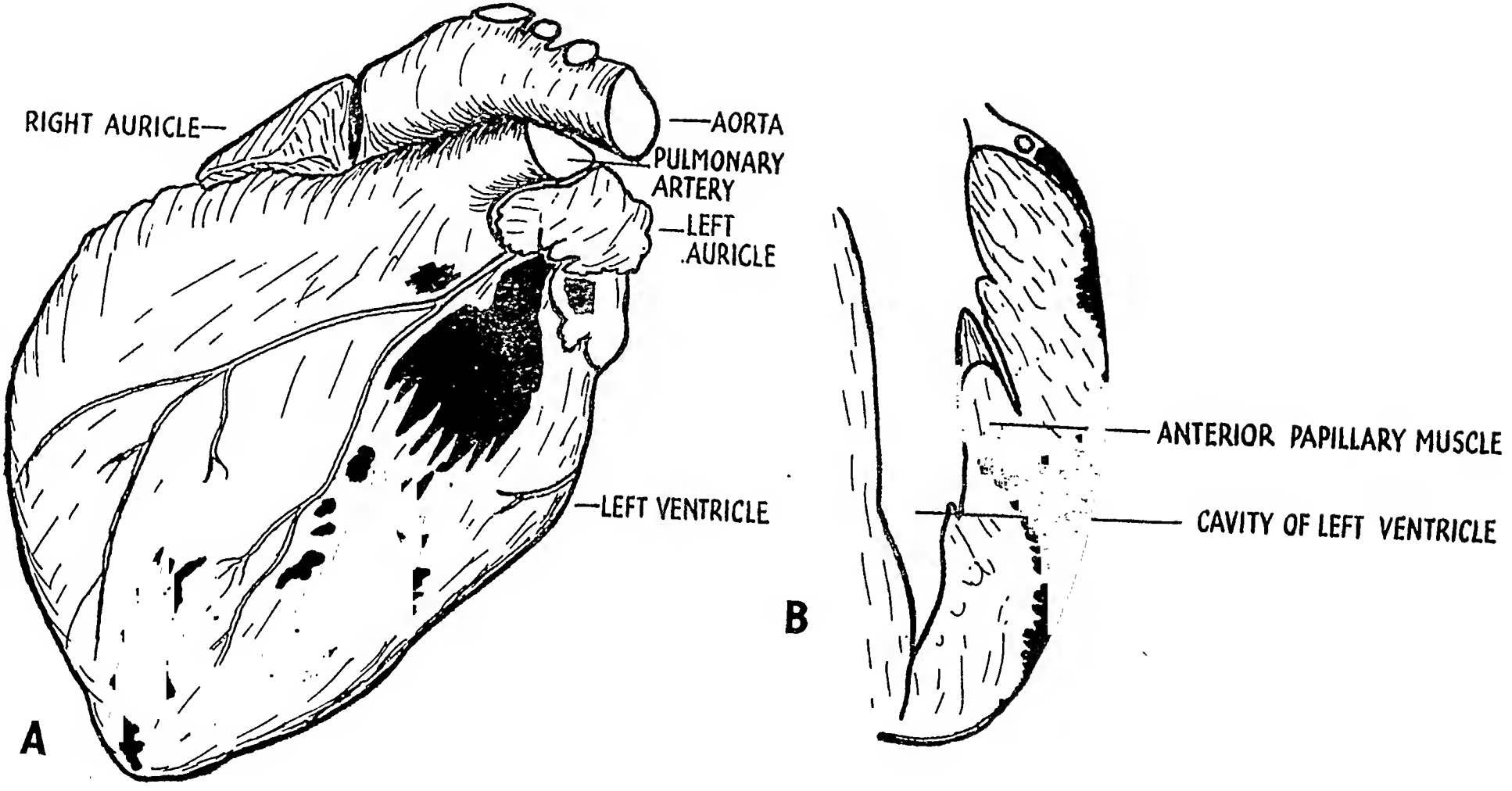
The lungs showed gross congestion of the capillaries and small arteries and veins. Most of the alveoli were filled with serous fluid containing few to many red blood cells. Phagocytic cells laden with hæmosiderin were numerous in the alveolar exudate. The bronchioles and bronchi contained a similar exudate. Free polymorphs were numerous throughout the walls of many of the bronchi, but there was little activity by mucus-secreting cells.

Commentary

(1) *The Type of Accident.*

This was a clear case of compression of the thorax, where the weight on the back pressed him against the ground. There are numerous records of heart injury from such an accident, with and without fractures of the bones of the thorax. It is in the young, with an elastic chest wall, that fractures are less common.

Beck (1940) gives the following list of injuries as causes of non-penetrating wounds or contusions of the heart : falls from a height; impact of a heavy force to the chest; the impact of the steering wheel of a car (this is the commonest accident); the passage of a wheel over the chest; and impact by a fist, a golf ball, or a horse's hoof on the front of the chest. He writes: " Any



Life-size drawings showing the distribution of the bruising of the heart.
(A) Surface of the heart, showing the bruising over the whole lateral aspect and anteriorly near the apex.
(B) Section of the left ventricle showing the depth of the bruising; only in one place did it extend to just beneath the endocardium.

part of the heart can be bruised, any of the chambers ruptured, and any of the valves can be torn." He states that the heart may be ruptured if the body is engulfed and the lower part buried.

(2) *The Site of the Heart Lesion and the Type.*

In this case the lesion was confined to bruising of the wall of the left ventricle; it was sub-pericardial, as shown in the drawing. In the region of the papillary muscle it just reached the endocardium. There was no rupture of the muscle fibres nor injury of the pericardium.

In Warburg's series (1938 and 1940) of non-penetrating wounds of the heart, there were 66 post-mortem records, of which 12 showed rupture of the heart and 6 contusion of the myocardium without rupture. Pericarditis was recorded in a number of cases. Of late results, there were 6 cases of cardiac aneurysm. In a number of the records there was evidence of disease due to natural causes, and in some the evidence of trauma was not convincing. Bright and Beck (1935) analysed 152 cases of rupture of the heart from trauma, in which the left ventricle was ruptured in 37, and each of the other chambers in 30 or more instances. In several instances more than one chamber was ruptured, and in 11 the inter-ventricular septum was torn. They recount 11 instances of failure without rupture, and 12 of recovery. Beck (1940), however, in commenting on these figures and comparing them with animal experiments, in which recovery is the rule, concludes that contusion of the myocardium is a common lesion, and is overlooked frequently.

An interesting study is the question of contusion developing chiefly under the endocardium. Warburg (1938) records such a condition, and also 6 cases of cardiac aneurysm following trauma. In these it would seem reasonable to suppose that the original lesion had been sub-endocardial. Groom (1897), in his case of delayed rupture of the left ventricle, noted that it appeared to have developed from within outwards.

We have one record of a partial rupture of the left ventricular wall extending from the endocardium about half way through the muscle. This lesion also involved the base of the papillary muscle. It was in a young man, who crashed in an aeroplane and had numerous other injuries, including rupture of the right ventricle.

Recently we have obtained a heart with sub-endocardial contusions following " cardiac massage " by a surgeon, when the heart ceased beating under an anæsthetic.

For three years we have made a special study of the heart in all post-mortem examinations after accidents. The variety of injuries met with confirm Beck's observations, that any part of the heart may be ruptured. The site of the lesion need not bear any obvious relation to the situation of the blow.

One justification for publishing this brief note is to emphasize the clinical interest to be found in medico-legal necropsies.

(3) *The Clinical Symptoms.*

The essential features were crushing of the chest; a latent period so far as obvious cardiac symptoms were concerned; and then, three and a half hours

later, circulatory failure in the form of acute pulmonary œdema. This last symptom is of interest in view of the damaged left ventricle, and suggests failure of that part of the heart muscle. We noted similar symptoms (Barber, 1938) in a man who recovered after a blow over the chest. It was concluded that he had sustained a contusion of the left ventricle. A time interval, varying in length, between the injury and any symptoms suggesting heart muscle trauma is usual, and has been a feature of clinical histories from this hospital (Barber, 1940).

Kissane (1937) recorded a series of 15 cases of contusion of the heart: 2 were complicated by a valve rupture, 2 by auricular fibrillation, and in 3 there were fractures. Of the 8 remaining, 4 had symptoms of cardiac distress immediately, and in 4 there was some delay.

Summary

A fatal case of contusion of the myocardium has been described; there was no rupture of the heart muscle. The morbid anatomy has been compared with other records.

Reference is made to clinical histories, already published from this hospital, suggestive of recovery from contusion of the myocardium.

References

Bright, E. F., and Beck, C. S. (1935). *Amer. Heart J.*, **10**, 293.
Beck, C. S. (1940). *Diagnosis and Treatment of Cardiovascular Disease.* Edited by Stroud, Philadelphia, Vol. **2**, 1157.
Barber, H. (1938). *Brit. med. J.*, **1**, 433.
—— (1940). *Ibid.*, **2**, 520.
Groom, W. (1897). *Lancet*, **1**, 1202.
Kissane, R. W. (1937). *Contusion of the Heart.* The Ohio State University, Columbus.
Warburg, E. (1938 and 1940). *Subacute and Chronic Pericardial and Myocardial Lesions due to Non-Penetrating Traumatic Injuries.* Copenhagen.
—— (1940). *Brit. Heart J.*, **2**, 271.

RUPTURED AORTIC VALVE WITH MYCOTIC ANEURYSM DUE TO ACUTE BACTERIAL ENDOCARDITIS

BY

C. W. CURTIS BAIN AND S. WRAY

From the Cardiographic and Pathological Departments, Harrogate General Hospital

Received March 28, 1941

Although mycotic aneurysms due to bacterial endocarditis are a recognized cause of rupture of one or more cusps of the aortic valve, the following case is of interest owing to the absence of fever.

CASE REPORT

Mrs. R. W., aged 48, was seen on September 16, 1940, with Dr. Bessie Brown. Two weeks previously she had begun to have attacks of shivering. Two days later she was taken ill in a cinema, and on her way home in the black-out collided with a lamp post. This gave rise to pain in the front of the chest on the right side, but there was no bruising. On the following day she was forced to remain in bed on account of retching associated with a dry, irritating cough and with shortness of breath. During the few days prior to examination streaks of blood had been coughed up, and dyspnœa had become increasingly severe; she had lost all desire for food and the tongue had been furred. The illness was afebrile throughout.

Examination revealed a stout, apprehensive woman, looking rather pale. The pulse was intermittent at a rate of about 90. The blood pressure was 150/30 mm. The apex impulse was not palpable, owing to the thick chest wall. The first sound at the apex was clear, but the second sound was followed by a rough diastolic murmur, which could be traced up the left border of the sternum and was audible at the second right space; there was no thrill. Crepitations were present at the bases of both lungs; they extended further up the back on the right side than on the left. The liver was not enlarged. There were no petechiæ; no Osler's nodes; and the spleen was not palpable.

The combination of the rapid onset of left ventricular failure with the murmur of aortic incompetence and a greatly increased pulse pressure suggested a ruptured aortic valve, and she was admitted to hospital on the following day for investigation regarding the possibility of a bacterial endocarditis.

The blood showed a moderate secondary anæmia (hæmoglobin, 70 per cent, red cells, 3·6 millions). The leucocytes numbered 22,900 (polymorphs, 82 per cent). The Wassermann reaction was negative. The urine contained albumen, a few red cells, and a trace of pus. The temperature remained sub-normal throughout, and on this account no blood culture was made.

The electrocardiogram on admission showed a 2:1 A-V block, with an auricular rate of 124 and a QRS of 0·08 sec. (Fig. 1), but six hours later the

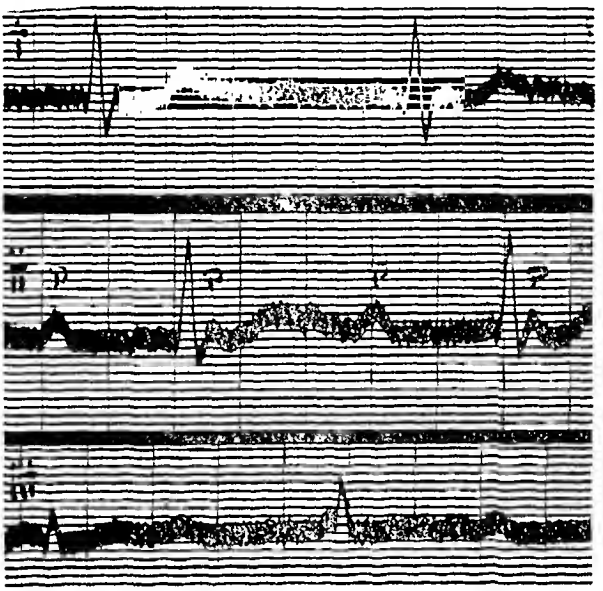


FIG. 1.—17/9/40. 2:1 A-V block (A, 124; V, 62): QRS, 0·08 sec.

auricular rate had risen to 148 and the QRS was 0·12 sec. Digoxin (0·25 mg.) was given four hourly and led to considerable clinical improvement, but the dose was halved after 12 tablets (3 mg.) had been given, since the ventricular complexes

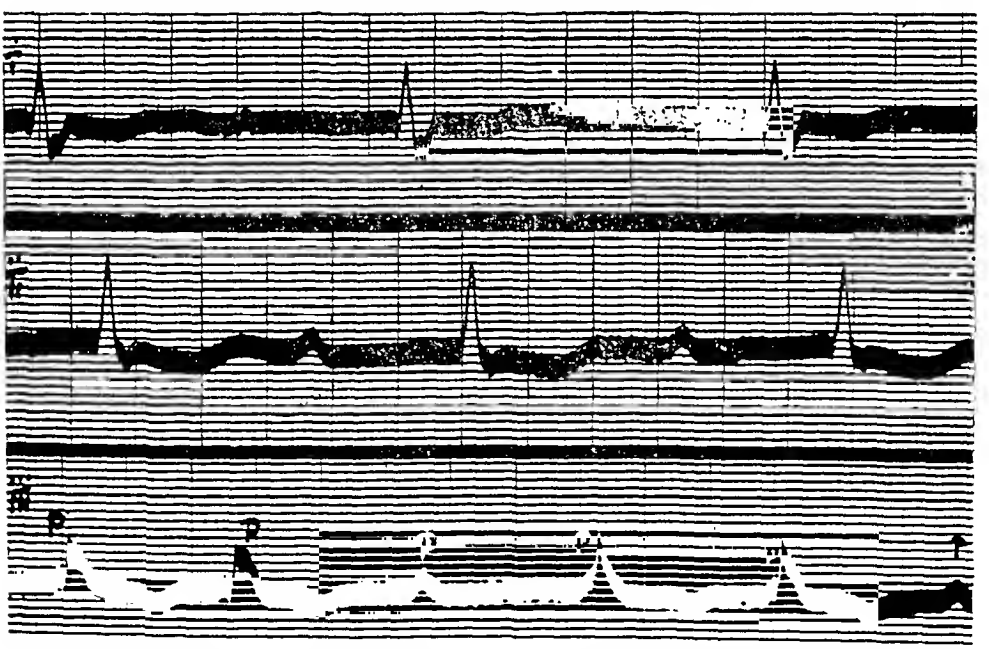


FIG. 2.—19/9/40. 2:1 A-V block in leads I and II (A, 106; V, 53) with right bundle branch block (QRS, 0·12 sec.). There is some depression of the S–T interval. In lead III there is an admixture of 2:1 block and 1:1 rhythm (P–R, 0·56 sec.).

had become those of a type B right bundle branch block with depression of the S–T interval, although the auricular rate had fallen to 106 (Fig. 2). Four days later 1:1 rhythm returned at a rate of 74 and the ventricular complexes were becoming normal. They were quite normal in another four days (Fig. 3.

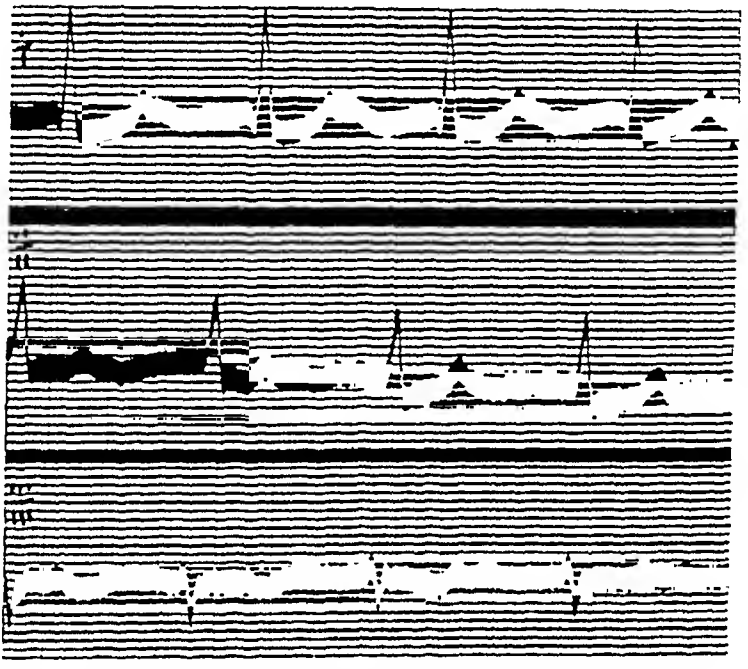


FIG. 3.—26/9/40. 1 : 1 rhythm at a rate of 74 (P–R, 0·50 sec.). A sinus irregularity gives rise to an apparent variability in the A-V block.

Sept. 26); the P–R interval was 0·50 sec., although a sinus irregularity gave rise to an apparent variability in the A-V block. On September 30, pulmonary œdema set in with further hæmoptysis, and she gradually sank and died on October 2, fifteen days after her admission to hospital. Normal ventricular complexes and 1:1 rhythm were still present a few hours before death.

AUTOPSY

Heart. The heart weighed 425 g., the relative thickness of the right and left ventricular walls being normal. The aortic valve was grossly incompetent, owing to a complete rupture of the right posterior cusp (Fig. 4). Around the site of the rupture, and particularly behind the damaged valve, there was much vegetative proliferation, which on the whole was firmly adherent and extended deeply into the membraneous part of the ventricular septum. There were further wart-like vegetations at the base of the left posterior cusp. The remaining valves were normal. There was no evidence of congenital abnormality.

On opening the right auricle a tumour was seen situated immediately above the junction of the anterior and medial cusps of the tricuspid valve (Fig. 5). The tumour was cone-shaped, with a height and basal diameter of about 1 cm.

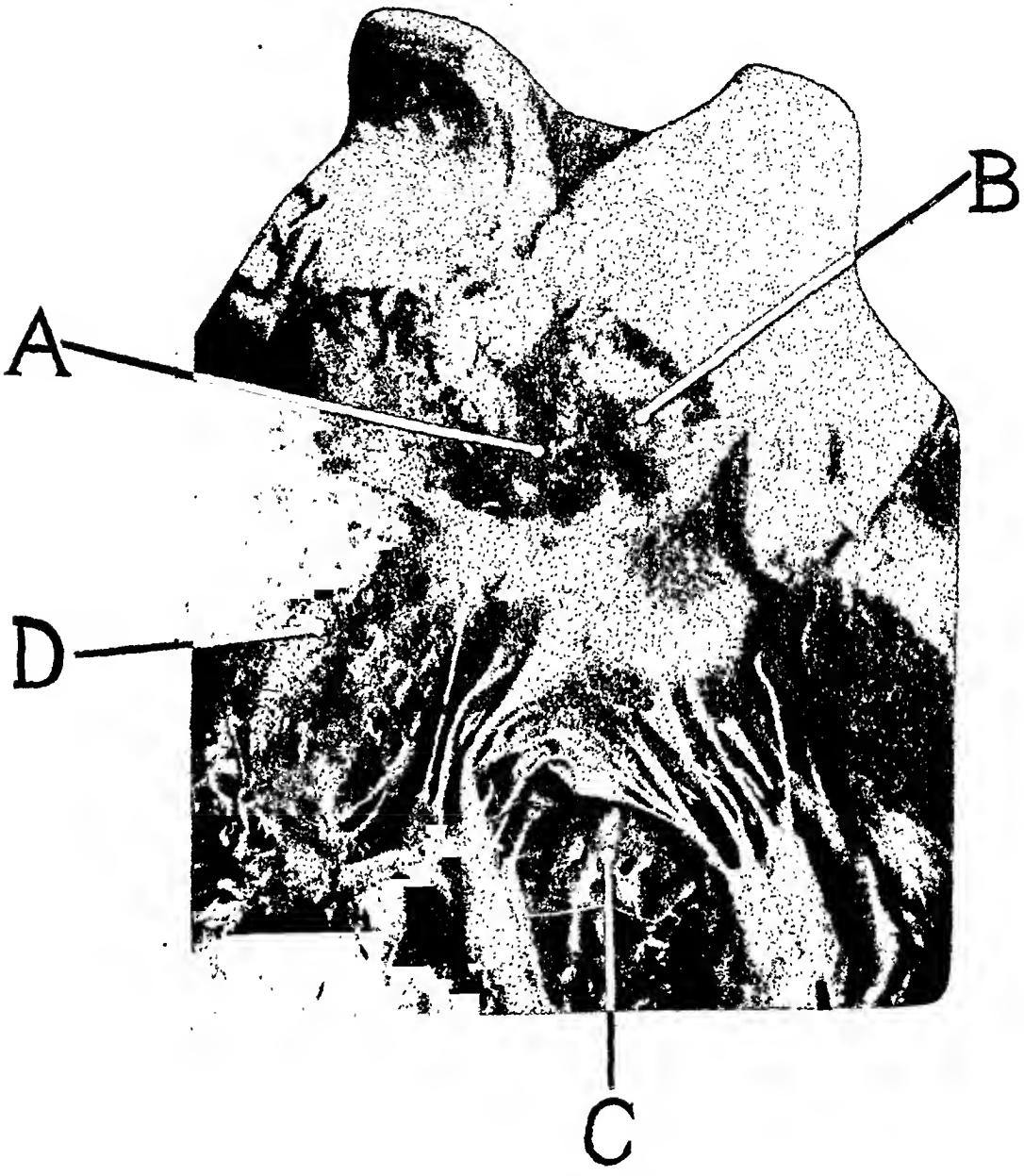


FIG. 4.—Aortic valves showing rupture of the right posterior cusp.

(A) Ruptured aortic valve and excavating cavity.
(B) Left posterior cusp of aortic valve.
(C) Left ventricle.
(D) Septal wall.

It was of the same colour as the auricular wall, was of a firm consistency, and had a smooth surface; it could not be moved on its base. The tumour emerged from the membraneous part of the septum, and on section proved to be an aneurysmal sac that communicated directly with the excavating cavity round the ruptured valve.

Other Systems. There was some œdema and congestion of the lungs,

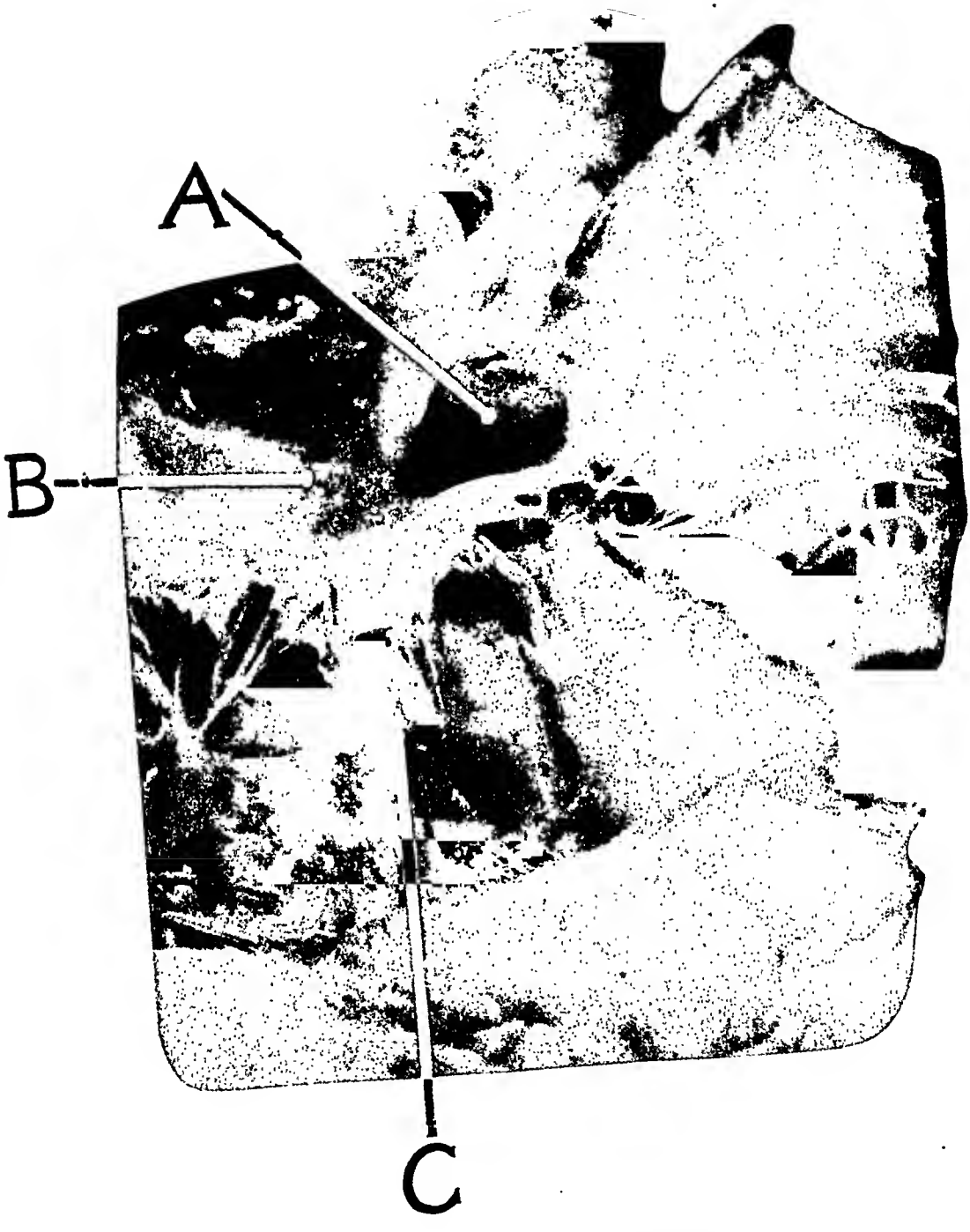


FIG. 5.—Right side of the heart showing the aneurysm.

(A) Aneurysm projecting into right auricle.
(B) Right auricle.
(C) Right ventricle.

especially at the right apex. There was a small right hydronephrosis. The spleen was normal.

Histology

Sections were prepared from the vegetations around the aortic valve and the adjacent myocardium, and also from the centre of the auricular tumour. These were stained with hæmatoxylin, eosin, and Gram's stains.

1. *Aortic Vegetation.* Whilst a little of the tissue consisted of platelet thrombus, the greater part was composed of a loose stroma, which was grossly infiltrated with round cells and polymorphs; numerous red blood cells were also present.

2. *Wall of the Aneurysm.* The aneurysmal wall consisted of three distinct layers. The outer layer was composed of dense fibrous tissue, the middle layer of muscular tissue together with a few fibroblasts and lymphocytes, whilst the inner layer was chiefly platelet thrombus containing a few fibroblasts and polymorphs.

3. *Heart Muscle.* There was no evidence of rheumatic disease.

The diagnosis after autopsy was a ruptured aortic valve with a mycotic aneurysm due to acute bacterial endocarditis.

Discussion

Except for the first two days of malaise the patient was under observation in bed and the temperature never rose above normal. Horder (1908) noted that fever was absent in five out of his one hundred and fifty cases, but he thought it was unlikely that these cases were afebrile throughout, and that they had probably come under observation during an afebrile phase. Perry (1936) had one case in which the temperature was normal for thirteen weeks. Possibly the rapid course of the illness with death from heart failure four weeks after the onset did not allow time for fever to develop.

It is uncertain if digitalis exercises any effect upon intra-ventricular conduction. White (1937) thought that it did to some extent, but Comeau and Hamilton and White (1938) could find no evidence of such an action. The situation of the aneurysm made some interference with conduction inevitable, and complex changes in conduction have been recorded in a similar case by Wishaw (1940). The widening of the QRS began before digitalis was given, during a period of increasing heart failure, and this association has been noted frequently in transient bundle branch block (Comeau, Hamilton, and White, 1938). On the other hand, the right branch block increased while clinical improvement was taking place, and did not regress until four days after the digitalis dosage had been reduced; neither did it recur, although death took place from pulmonary œdema. In the absence, however, of evidence from other sources of a similar action of digitalis it would appear more likely that the transient right branch block was occasioned by the heart failure rather than by digitalis.

SUMMARY

A case of rupture of the aortic valve with a mycotic aneurysm due to bacterial endocarditis has been described. The temperature was sub-normal throughout the illness. Death took place quickly with signs of left ventricular failure.

REFERENCES

Comeau, W. J., Hamilton, J. G. M., and White, P. D. (1938). *Amer. Heart J.*, 15, 276.
Horder, T. J. (1908-9). *Quart. J. Med.*, 2, 289.
Perry, C. B. (1936). *Bacterial Endocarditis*, p. 60.
White, P. D. (1937). *Heart Disease*, Second ed., New York, p. 548.
Wishaw, R. (1940). *Med. J. Australia*, 1, 695.

MAUDE ABBOTT

Members of the Cardiac Society learned with deep regret of the death of Dr. Maude Abbott, our only woman honorary member, on September 3, 1940.

She was born in Quebec in 1869 and passed her medical life almost entirely in her native country of Canada. Some years were spent in Scotland, where she qualified in 1897; and from 1923 to 1925 she was Professor of Pathology and Bacteriology at the Women's Medical College in Philadelphia. But her medical career was bound up with McGill University, Montreal, where she served as Curator of the Pathological Museum from 1899, as Lecturer in Pathology from 1912 to 1923, and as Assistant Professor of Medical Research from 1925. Her University recognized her faithful service and high achievement by conferring upon her the honorary degree of M.D., and later of LL.D.

In congenital malformations of the heart she found her life interest, and in 1905 Sir William Osler invited her to write on Congenital Cardiac Disease for his *System of Medicine*. From that time patient and methodical research on this subject became her ruling passion, and established Maude Abbott as the greatest authority in the world on congenital heart disease. The main basis of her work was an exhaustive and critical study of pathological specimens wherever these had been reported or were to be found, with the ultimate purpose of clinical classification and recognition. The results are to be found in her contributions to Blumer's *Bedside Diagnosis*, and to Nelson's *Loose-Leaf Medicine*, and notably in the monumental *Atlas of Congenital Cardiac Disease* published by the American Heart Association in 1936. It is an outstanding feature of Maude Abbott's work that, beginning firmly on the pathological footing, she raised from what was merely a disconnected and unproductive series of cases a distinct and defined branch of cardiology—and this with a facility of diagnosis now, of course, rapidly increasing because of the special help afforded by electrocardiography and radiography.

In 1913, the Seventeenth International Congress of Medicine was assembled in London, and Dr. Maude Abbott had the pleasure of attending a meeting of the International Association of Medical Museums, which was founded largely owing to her initiative and of which she became the permanent secretary. Again she found in Osler a powerful friend and supporter; and it was characteristic that she made herself responsible as editor for the classified and annotated bibliography of Sir William Osler's publications, printed in Montreal. From 1907 to 1938 she was editor of the *Journal of Technical Methods and Bulletin of the International Association of Medical Museums.*

Maude Abbott was a woman of simple and unaffected charm, easy to know

and pleasant to meet. The expression of her eyes was eager and searching, yet soft with an engaging kindliness. She travelled a good deal and made friends wherever she went. Unspoiled by success, she was happy and content with the knowledge that she had completed her great and complicated task. She had applied that clean-cut and orderly mind in clearing up the cardiac malformations of the child, and she will be remembered as a pioneer " not content with fragments and scattered pieces of Truth."

JOHN PARKINSON.

KAREL FREDERIK WENCKEBACH

This great Dutch physician, to whose memory a tribute is now paid, was born at The Hague on March 24, 1864. He proceeded from the Gymnasium to the University of Utrecht and in 1888 graduated doctor of medicine with a thesis entitled "*Over den bouw en de ontwikkeling der Bursa-Fabricii.*" While still in Utrecht he began those brilliant researches on extrasystoles, conduction defects, allorrhythmia, and alternation that were published between the years 1898 and 1901. By critical analysis of arterial pulse tracings, before the advent of the polygraph or electrocardiograph, he was the first to show that those disturbances of the human heart represent disorders of properties inherent in the myocardium and are of the same nature as those known to occur in the experimental animal. That great achievement was his alone and, together with Mackenzie's studies of the venous pulse, it initiated a new era in cardiology. The functional activity of the heart in health and disease, its response to drugs, its very structure had now to be studied anew. This in turn paved the way for a wider and better knowledge of other factors than the heart that promote the circulation of the blood and interstitial fluid. Wenckebach was indeed one of the foremost leaders in the renaissance of clinical medicine at the dawn of this century.

Two years after his appointment to the Chair of Medicine in Groningen in 1901, the publication of his first and greatest work "*Die Arhythmie als Ausdruck bestimmter Funktionsstörungen des Herzens*" brought him world-wide fame. In 1911 he passed to the Chair of Medicine in Strasburg and in 1914 to that in Vienna, where a great medical school had been founded, two centuries earlier, by another Dutchman, van Swieten, a pupil of Boerhaave. All Wenckebach's work was characterized by keen clinical acumen, by the utmost precision, and by close correlation of clinical research with that in the laboratory. Graduates were drawn to his clinic from many lands, and notably from the United States. He resigned his chair in 1929.

In addition to his epochal work on cardiac irregularity, of which there is an English translation, he wrote on the radiography of the chest, artificial pneumothorax, beri-beri, circulatory failure, and other subjects. His chief contributions to medical literature between 1898 and 1924 are given in "*Die unregelmassige Herztatigkeit,*" the monumental treatise of which he and Winterberg were the joint authors. A further list is given on page 143. He was a founder and one of the editors of the "Wiener Archiv für innere Medizin." Three terms bear his name: Wenckebach's periods, the slowing of auriculo-ventricular conductivity with periodic dropping of ventricular beats; Wencke-

bach's sign, the paradoxical movements of the chest in chronic mediastino-pericarditis; and Wenckebach's bundle, a band of muscle passing from the superior vena cava to the right auricle.

Wenckebach always felt at home in our country, closely akin to his native land. As a young man he visited Mackenzie in Burnley, and while Gibson's guest in Edinburgh was the central figure of some amusing but apocryphal tales. He opened a discussion on digitalis in London in 1910, and that on heart failure at the Seventeenth International Congress of Medicine in London in 1913. In 1919, when Eastern Europe had been laid waste and destitution and disease were rife, he initiated the Relief Mission to Vienna. In 1928 he was a delegate to the tercentenary celebration in London of the publication of "*De motu cordis*" and was the St. Cyres Lecturer at the National Hospital for Diseases of the Heart. In the following year he delivered an oration at the sesqui-centenary celebration of the Birmingham General Hospital. In 1930 he received the honorary degree of LL.D. from the University of Edinburgh; he made a tour through the Highlands and a pilgrimage to the Research Institute founded by his friend, Sir James Mackenzie, in St. Andrews. Three years later he was again in Edinburgh as the Gibson Memorial Lecturer at the Royal College of Physicians.

Many honours were bestowed upon him. He was awarded the Order of Merit of the Austrian Republic, was a Fellow of the Koninklijke Akademie van Wetenschappen te Amsterdam and of the Kaiserliche Akademie der Wissenschaften, an Honorary Fellow of the Royal College of Physicians of London, the Royal College of Physicians of Edinburgh, the Royal Faculty of Physicians and Surgeons of Glasgow, and the Royal Society of Medicine, an Honorary Member of the Medico-Chirurgical Society of Edinburgh and the Cardiac Society of Great Britain and Ireland, and a Corresponding Foreign Member of la Société Française de Cardiologie.

The charm of the English countryside and the gaiety of Franz Hals' canvases appealed strongly to Wenckebach for he was a lover of beauty in nature and art. He was a warm-hearted man with a keen sense of humour. Among his many friends he counted Gibson, Clifford Allbutt, Osler, Keith, and Cushny. He was a modest man, saying "In medical science there are vast realms of which I have no special knowledge" and, again, "No, I am not a great man; I am a happy man." His particular charm was a radiant joie de vivre and to him the wine and salt of life were given in full measure.

W. T. RITCHIE.

A FURTHER NOTE OF WENCKEBACH'S MEDICAL CONTRIBUTIONS

1. Beiträge zur Entwicklungsgeschicte der Knochenfische. *Arch. mikrosk. Anat.*, 1886, 28.
2. Ueber den Pulsus Alternans. *Z. klin. Med.*, 1902, 44, 218.
3. Ueber an der Atrioventrikulargrenze ausgelöste Systolen bei Menschen (with James Mackenzie). *Arch. Anat. u. Phys.* (Phys. Abt.), 1905, 235.

4. Les Irrégularites du Coeur. *Arch. Mal. Coeur*, 1908, **1**, 65.
5. Ueber Heilung des chronischen (tuberculösen) Empyems mittelst künstlichem Pneumothorax. *Mitt. Grenzgeb. Med. u. Chir.*, 1909, **19**, 842.
6. Herzinsufficienz und Herzschwäche. *XVIIth Internat. Congr. Med.*, 1913, Sect. VI, 187.
7. The Radiology of the Chest. *Arch. Roent. Ray.*, 1913–14, **18**, 169.
8. Cinchona Derivatives in the Treatment of Heart Diseases. *J. Amer. med. Ass.*, 1923, **81**, 472.
9. Angina Pectoris and the Possibilities of its Surgical Relief. *Brit. med. J.*, 1924, **1**, 809.
10. Toter Punkt, " Second Wind," and Angina Pectoris. *Wien. klin. Wschr.*, 1928, **41**, 1.
11. Heart and Circulation in a Tropical Avitaminosis (Beri-beri). *Lancet*, 1928, **2**, 265.
12. The Use of Foxglove at the Bedside. *Brit. med. J.*, 1930, **1**, 181.
13. Herz und Kreislauf-insuffizienz. Dresden and Leipzig, 1930. (Third Edit., 1934.)
14. The Riddle of the Beri-beri-Heart. *Libman Ann. Vol.*, 1932, **3**, 1197.
15. Das Beri-beri-Herz. Berlin and Wien, 1934.
16. Stossdämpfer im Herzen. *Z. Kreisl.*, 1938, **30**, 441.

CHARLES LAUBRY

It is with great regret that we learn, from a brief notice in a Swiss journal, of the death at Nantes of Professor Charles Laubry, of Paris.

The great traditions of the Paris school of cardiology have been handed down in direct line from master to pupil for over a century, starting with Corvisart and passing in turn to Bouillaud, to Potain, to Vaquez, and finally to Laubry. All these have been masters of bedside teaching and clinical observation. In our own time, the physicians trained and inspired by Vaquez, among whom Laubry was prominent, have exercised a powerful influence on cardiological teaching, especially in Latin Europe and Latin America, comparable in some ways with Mackenzie's influence in English-speaking countries. In 1908, Vaquez, assisted by Laubry and Aubertin, founded the *Archives des Maladies du Cœur*, which for over thirty years has been a mainstay of French cardiology.

Graduating from the école Vaquez, Laubry established his own clinic, which, after several moves, eventually settled at the Hôpital Broussais in 1925. In this ancient and dilapidated building, situated in a poor quarter of the south of Paris, and almost unaltered since the war of 1870, Laubry organized a complete cardiological centre. Here it was my privilege to pass a month or so in 1926, when Laubry's reputation as a teacher was beginning to attract visitors from abroad.

Laubry was a man of most attractive personality. Overflowing with good nature, paternal in manner, animated in speech, he possessed in full measure all those qualities that we most admire as typically French. He was, above all, a great clinical teacher, at his best at the bedside or in the out-patient department. Here he would give impromptu a polished and complete clinical lesson without ever becoming tedious, so that one finished a ward round with the feeling that time had passed all too quickly.

Though by no means slavishly accepting all the views emanating from the Vaquez clinic at the Pitié, and rejecting, for example, the elaborate mensuration of the orthodiagram practised by Bordet, Laubry was unwavering in his loyalty and devotion to his old chief, to whom he delighted to pay public tribute. His interests covered the whole field of cardiovascular problems, and it is difficult to single out any particular aspect of his work; perhaps his contributions to the radiology of the heart deserve special mention.

Early convinced of the importance of X-ray examination through his association with Vaquez and Bordet, Laubry was fortunate in having as his assistant Robert Chaperon, a pioneer worker in this particular field; it was he

who developed the technique of radio-opaque injection of the individual heart cavities and great vessels *in situ* in the cadaver, as a method of studying the anatomy of the heart; and important papers on the vascular pedicle and the composition of the lung root shadows resulted. After the untimely death of Chaperon, this work was continued and extended in co-operation with Heim de Balzac, and the fruits of many years of patient investigation were incorporated in the large treatise "*Radiologie Clinique du Cœur et des Gros Vaisseaux*," published by Laubry and his associates in 1939 shortly before the war. This book will certainly have a permanent value in reference to all aspects of the radiological anatomy of the heart, normal and pathological.

Though his reputation rested more on the spoken than on the written word, Laubry wrote much. His book "*Traité des Maladies Congénitales du Cœur*," written jointly with Pezzi, appeared in 1921 and is still widely quoted. His "*Leçons de Sémiologie Cardiovasculaire*," published in 1924, is perhaps his best-known book, and makes delightful reading, bearing comparison with the famous clinical lessons of Merklen. In 1930, he published a large text-book on heart disease, which, though excellently produced, was rather a bulky volume and never attained the popularity of Vaquez' text-book.

No account of Laubry's work would be complete without some mention of the "*bruit de galop*." This sign, long neglected in England, had been described in masterly fashion by Potain in 1875, and seemed to possess a singular fascination for Laubry, who paid great attention to it in his teaching. With Pezzi, he wrote a monograph on gallop rhythm in 1926, and also made it the subject of his St. Cyres Lecture, delivered in London in 1937.

Laubry was never a *professeur agrégé*, and was not therefore normally eligible for a professorial chair; but when the time drew near for him to retire as a *Médecin des Hôpiteaux*, a special chair of Clinical Cardiology was created so that his services as a teacher could be retained. He accomplished much for French cardiology besides his purely scientific contributions. After the death of Vaquez, he took over the direction of the *Archives des Maladies du Cœur*, and greatly improved the standard of its production, at the same time excluding from its scope diseases of the blood. In 1937 he initiated the Société Française de Cardiologie, of which he was nominated first president, Prof. Clerc and Dr. Gallavardin being joint vice-presidents. Whereas the *British Heart Journal* was started by the Cardiac Society, in France the reverse occurred, for the society was formed by the journal through its editorial committee. Laubry next envisaged the formation of an international society of cardiology, and broached the subject on the occasion of a dinner given in his honour in London in 1937. Unhappily events were to prove unfavourable to his project.

All who knew Laubry will wish to join with me in paying affectionate tribute to his memory, and all members of the Cardiac Society will share our regret in the passing of another of our distinguished honorary members.

D. EVAN BEDFORD.

TRICUSPID STENOSIS;
WITH PARTICULAR REFERENCE TO DIAGNOSIS AND PROGNOSIS

BY

W. TREVOR COOKE * AND PAUL D. WHITE

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Recent experience with several cases of tricuspid valve disease, attending out-patient clinics without arousing any thought of this valve lesion, has stimulated our interest in the subject and has emphasized the inadequacy of most discussions on the subject.

It has become almost traditional to state that tricuspid stenosis is rare and that the diagnosis is difficult. Herrick (1897) wrote that the disease is so rare that the full details of every case should be reported. Mackenzie (1908) wrote that he had heard a tricuspid murmur only three times in his life. Osler and Gibson (1915) advocated caution in the diagnosis—" As a rule the physician is in a safer position if he limits his diagnosis to two valves: clinically, when lesions of three or four valves are determined with accuracy, mortifying post-mortem disclosures are not unlikely to follow." Lewis (1933) rather implies that the diagnosis is not worth making when he writes " I have not known the diagnosis, when made, affect the management of any case." Strümpell and Seyfarth (1928) say that tricuspid valve disease is so rare as to have no practical importance. The stress that has been laid on the rarity and difficulty of diagnosis of the affection combined with statements such as those above, have tended to make the average practitioner forget that the tricuspid valve is not infrequently affected. Of the 250 reported cases collected by Zeisler (1932) the diagnosis had been made before death in only 31: of those, 14 were made by Dressler and Fischer (1929–1930) who reported 33 autopsied cases, but in their series it was only after their interest had been aroused that the diagnosis began to be made, resulting in the correct interpretation in 11 out of the last 14 cases.

We have, therefore, thought it worth while to consider if the diagnosis of tricuspid stenosis is after all entirely unimportant and to determine as clearly as possible the diagnostic criteria.

According to the pathologist, the tricuspid valve becomes stenosed when the ostium is reduced to between 10 and 11 cm., the normal being between 12 and 14 cm. (Cabot, 1926). White (1937) writes that stenosis of clinical importance

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and of such degree as to be diagnosable clinically in some cases is not reached until the ostium is reduced to 8 cm. or less.

The valve becomes incompetent for three reasons: (1) extensive scarring in which regurgitation accompanies stenosis; (2) slight shortening of the chordæ tendineæ or fibrosis of the valve edge resulting in regurgitation, without necessarily causing stenosis; and (3) dilatation of the valve ring due to myocardial infection, long standing congestive failure, or constitutional disease such as anæmia. The valve is diseased in the first and second instances, and defective though not diseased in the third; the functional disorder of the third instance may actually be more serious than organic valvular disease, at least as a manifestation of important trouble, though often it is only a transient condition.

Incidence and Pathology

A false idea of the incidence of tricuspid valve stenosis has been given by the numerous compilations of isolated case reports of the disease. There exists, moreover, a good deal of discrepancy between several of the analyses that have been published, doubtless dependent largely on the degree of stenosis. In Baltimore only 7 cases were found in 24,000 autopsies (Hirschfelder, 1910). Coombs (1924) gives the following figures of the incidence of valve injury in 97 cases of rheumatic heart disease, including the lesser as well as the greater degrees of involvement.

Total	Mitral	Aortic	Tricuspid	Pulmonary
97	97	57	35	2

These were combined in the following ways:

Mitral alone	27 cases
Mitral and aortic	35 ,,
Mitral and tricuspid	12 ,,
Mitral, aortic, and tricuspid	21 ,,
Mitral, aortic, tricuspid, and pulmonary	2 ,,

He does not give the relationship of these cases to the clinical signs, but later states that the incidence at Bristol of clinical tricuspid stenosis in rheumatic heart disease was 14 per cent. Cabot (1926) gives the incidence at 15 per cent while Dressler and Fischer put the incidence at 24 per cent.

Bland, Jones, and White (1935) analyzed the pathological findings in 100 cases of fatal rheumatic disease below the age of 21 in whom the diagnosis of tricuspid valve disease had not been made during life. Out of 100 cases, the mitral valve was affected in 98 instances, the aortic in 71, the tricuspid in 30, and the pulmonary valve in 5, and there was one case with no valves at all affected. The valve lesions, many of them acute with little or no deformity, occurred alone or combined as follows:

Mitral alone	23 cases
Aortic alone	1 case
Mitral and aortic	45 cases
Mitral and tricuspid	5 ,,
Mitral, aortic, and tricuspid	20 ,,
Mitral, aortic, tricuspid, and pulmonary	5 ,,

This group is selected, in that it is composed of cases dying of rheumatic fever: therefore one might suggest that they had more extensive heart involvement than a similar group having rheumatism over the same period of time, but surviving; and that therefore the incidence may naturally be expected to be higher. On the other hand, valve deformity sufficient to produce stenosis is less common in these younger cases, even though fatal; the myocardium is more involved than the valves. Yet it is fairly certain that cases surviving show a rather high incidence of tricuspid involvement, even though rarely progressing to a degree of much stenosis. Von Glahn (1927) examined 109 rheumatic heart cases at autopsy, grouping them into acute or chronic lesions, and found 19 acute and 26 chronic tricuspid valve lesions making a total of 45 or 41 per cent. Libman (1923) has always emphasized the high incidence of tricuspid involvement (not stenosis as such) in rheumatic heart disease; in one small series, he found the valve involved in 12 out of 18 cases of endocarditis. Thayer (1925) also found a high involvement (44 per cent). Cabot (1926) records 33 cases of tricuspid stenosis among 4000 autopsies between 1896 and 1919 at the Massachusetts General Hospital.

Our Series of Cases

We have analyzed the data on 30 cases of tricuspid stenosis proved post-mortem, and on 12 cases that we ourselves have studied during life—3 confirmed by autopsy, the others still alive but almost certainly correctly diagnosed. At the Massachusetts General Hospital between the years 1920 and 1937 inclusive, there have been 4300 autopsies; these included 217 cases of rheumatic heart disease, and in that series there was involvement of the tricuspid valve in 47 cases. Of these 47 there were 17 in whom the affection was probably of no clinical significance, being either an acute terminal rheumatic process or a bacterial endocarditis or one of the group that Libman states is common, slight scarring and fibrosis of a limited segment of the valve ring.

The valves affected in this whole group from 1920 to 1937 at the Massachusetts General Hospital consisting of 217 cases of rheumatic heart disease were as follows:

Mitral alone	59	cases
Aortic alone	11	,,
Mitral and aortic	100	,,
Mitral and tricuspid	7	,,
Mitral, aortic, and tricuspid	35	,,
Mitral, aortic, tricuspid, and pulmonary	5	,,
Total	217	,,

Thus there were 47 cases of tricuspid disease (22 per cent) among the 217, but only 30 (14 per cent) that were important in themselves (as definite tricuspid stenosis).

There is unfortunately no satisfactory way in the series of cases noted above of correlating the post-mortem data with the clinical signs of tricuspid disease that may have been present. The diagnosis was made before death in only 1 of the 30 cases and suspected in only 2 other cases. These 30 cases have

therefore been divided up by us quite arbitrarily into three clinical diagnostic groups according to whether or not the cases might have shown signs during life. Accordingly the clinical diagnosis justified by the data of the 30 cases of tricuspid stenosis was as follows:

1. Tricuspid stenosis and regurgitation of varying degree .. 19 cases
2. Possible functional impairment of tricuspid valve .. 9 ,,
3. Tricuspid ring dilatation alone .. .. 2 ,,

If these assumptions are correct, there would be roughly 9 per cent (that is, 19 out of 217 cases of rheumatic heart disease) of all cases of rheumatic valvular disease showing clinical signs of tricuspid stenosis and regurgitation.

There is one further fact to be considered statistically. In adults, tricuspid stenosis produces in its later stages a life of chronic invalidism, which lasts for very much longer than the invalidism produced by mitral valve disease alone. For this reason it is probable that these cases find their way to homes for the chronic sick rather than to the general hospitals, and so lower the post-mortem incidence of tricuspid disease in the hospitals.

As yet there is no large series of rheumatic heart cases that has been followed through from beginning to end, to give us a better idea of the true incidence. From the facts at present available, it is probable that one case in every ten of rheumatic heart disease of more than a few years' duration has organic disease of the tricuspid valve, at least moderate in degree.

Age and Sex

Herrick (1908) gives a summary of the ages at death of 187 reported cases of tricuspid stenosis: in his series and in our own series of 30 cases studied post-mortem they were as follows:

	Herrick's Series	Our Series
0–10 years	0	1
10–20 ,, ...	16	8
20–30 ,, ...	59	7
30–40 ,, ...	38	6
40–50 ,, ...	28	5
50–60 ,, ...	10	3
60–70 ,, ...	6	—
Age not given	30	—

Usually females have been more frequently affected than males (Duroziez, 1868; Herrick, J. B., 1897; Dressler and Fischer, 1929). In our 30 cases, 16 were males and 14 were females. In an additional later group of 12 cases that we have observed clinically, 7 were females and 5 were males.

Clinical Diagnosis

Duroziez (1868) reported 10 cases of tricuspid stenosis with ages varying from 22 to 64, and asserted that tricuspid disease was more common than was usually accepted. He was impressed by their marked cyanosis and by the fact that many could lie flat in bed in spite of gross cardiac deficiencies: in spite of marked valvular damage some were able to live to old age, and so he concluded

that the tricuspid lesion did not aggravate the mitral lesion. He drew attention to the systolic or diastolic murmur at the lower end of the sternum that pointed to the diagnosis, and wrote: "The disease should be diagnosed when the patient is a female, has a history of rheumatism, and of dyspnœa, palpitation, œdema, often with remissions and exacerbations, is cyanosed, has mitral stenosis with an enlarged right heart, particularly if the auricular enlargement can be made out. Especial value attaches to the persistent cyanosis. If in addition to this the patient has a separate murmur best heard over the ensiform or the fifth or sixth right costal cartilage, then the diagnosis becomes reasonably certain." This admirably summarizes the chief points. There is no one infallible diagnostic sign but there are numerous signs, any one of which should initiate a search for other clues.

The diagnosis may be suspected from the *history* alone as Levine and Thompson (1937) have pointed out. Any adult patient who has repeated attacks of œdema and ascites and yet is able to lead a sedentary life with the aid of diuretics and carry on with symptoms that ordinarily would cause the early demise of the patient, probably has tricuspid stenosis.

Several observers, most recently Wearn (1936), have commented on the peculiar colour, a mixture of jaundice and cyanosis, that is presented by these patients, pointing out that this should always suggest the possible diagnosis of tricuspid stenosis. Much reliance cannot, however, be placed on this sign inasmuch as its commonest pathogenesis lies in the inability of an engorged or diseased liver to excrete rapidly enough the blood pigment from a pulmonary infarct (so common in mitral stenosis with congestive failure), whether mitral stenosis alone or mitral stenosis with tricuspid valve disease is responsible for the trouble with the liver.

A patient with a rheumatic heart and ascites who is *able to sleep without extra pillows* probably has tricuspid stenosis. This is due to the lack of pulmonary vascular engorgement, as confirmed by X-ray study, resulting from the obstruction to the free flow of blood through the right heart.

Pulsation in the neck veins has for over one hundred years excited comment, with much argument as to whether the jugular polygram is diagnostic. Mackenzie (1894) pointed out that the deep (internal) jugular pulse in the neck is frequently thought to be arterial in origin because it is systolic in time. As a matter of fact it can very easily be shown to be venous in origin by light compression over the base of the neck (jugular bulb) with obliteration of the pulse (Fig. 1). The significance of this venous pulsation has recently been studied by us (White and Cooke, 1939). We found that although this pulse in the neck signifies only tricuspid regurgitation, whether due to organic disease or to functional regurgitation, *there is, nevertheless, a very strong probability, in fact almost a certainty, of the presence of tricuspid stenosis in the case of a patient in the fourth or fifth decade with rheumatic heart disease who has for years marked systolic deep jugular pulsation with little or no congestive failure* (see Cases 1 and 2, and Fig. 2).

The same conclusion holds good about *liver pulsation.* It is interesting that the observation is frequent in the follow-up records of a large number of the

histories we have studied, " that the patient still shows some signs of failure as evidenced by his large liver." On the other hand tricuspid stenosis may be

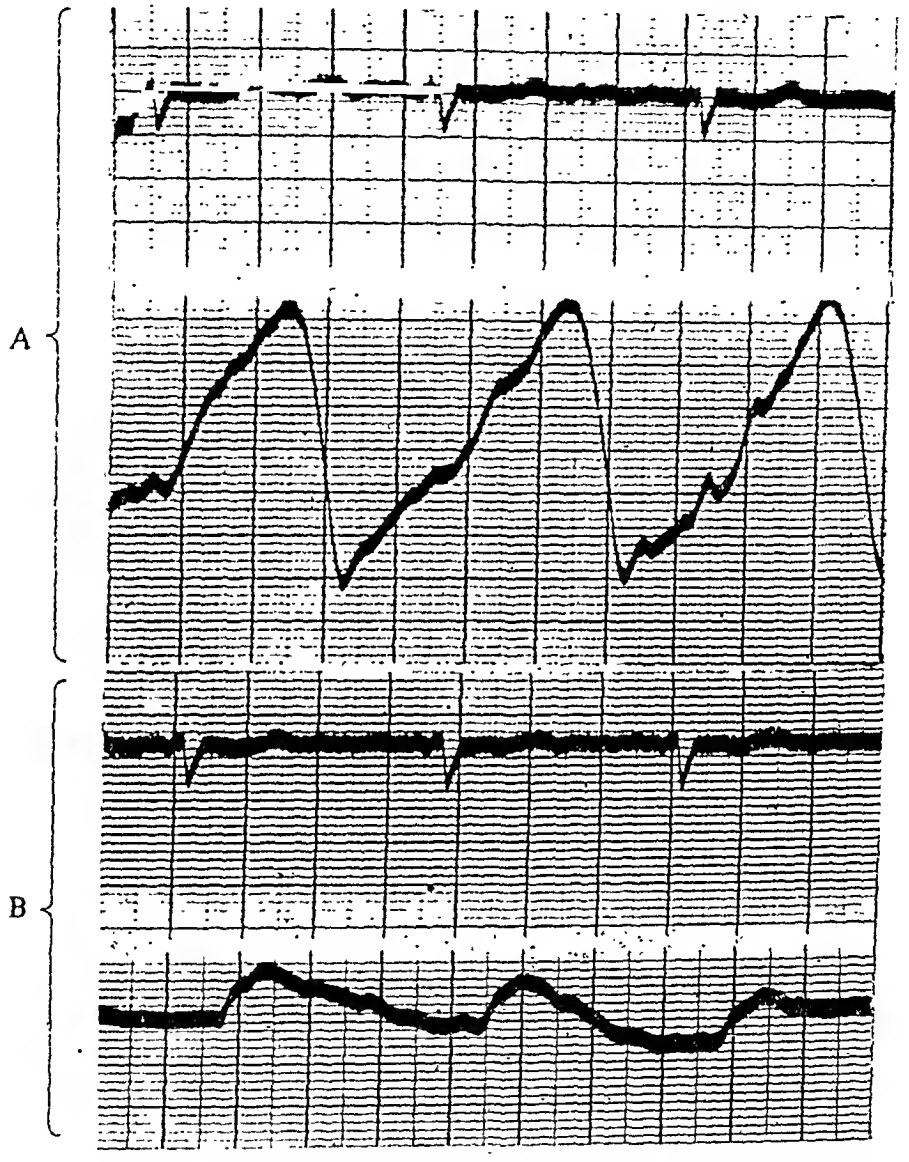


FIG. 1.—(A) Simultaneous tracings of electrocardiogram (lead 1), above, and of deep jugular pulsation, below, in a case of rheumatic, aortic, mitral, and tricuspid stenosis, with auricular fibrillation. Note the slow upward stasis curve with superimposed systolic pulse.
(B) Simultaneous tracings of electrocardiogram (lead 1), above, and of deep neck pulsation, below, after compression of the jugular bulb. The receiving cup has not been moved in its position. The jugular pulse has been obliterated and only the underlying carotid pulse remains (it is anacrotic).

present without venous pulsation either in the neck or in the liver (Clements, 1927; and others).

Tschilikin (1930) states that the only pathognomonic sign of tricuspid stenosis is a *localized diastolic murmur* at the lower end or to the right of the sternum. However, this sign is often, probably usually, absent, as in the

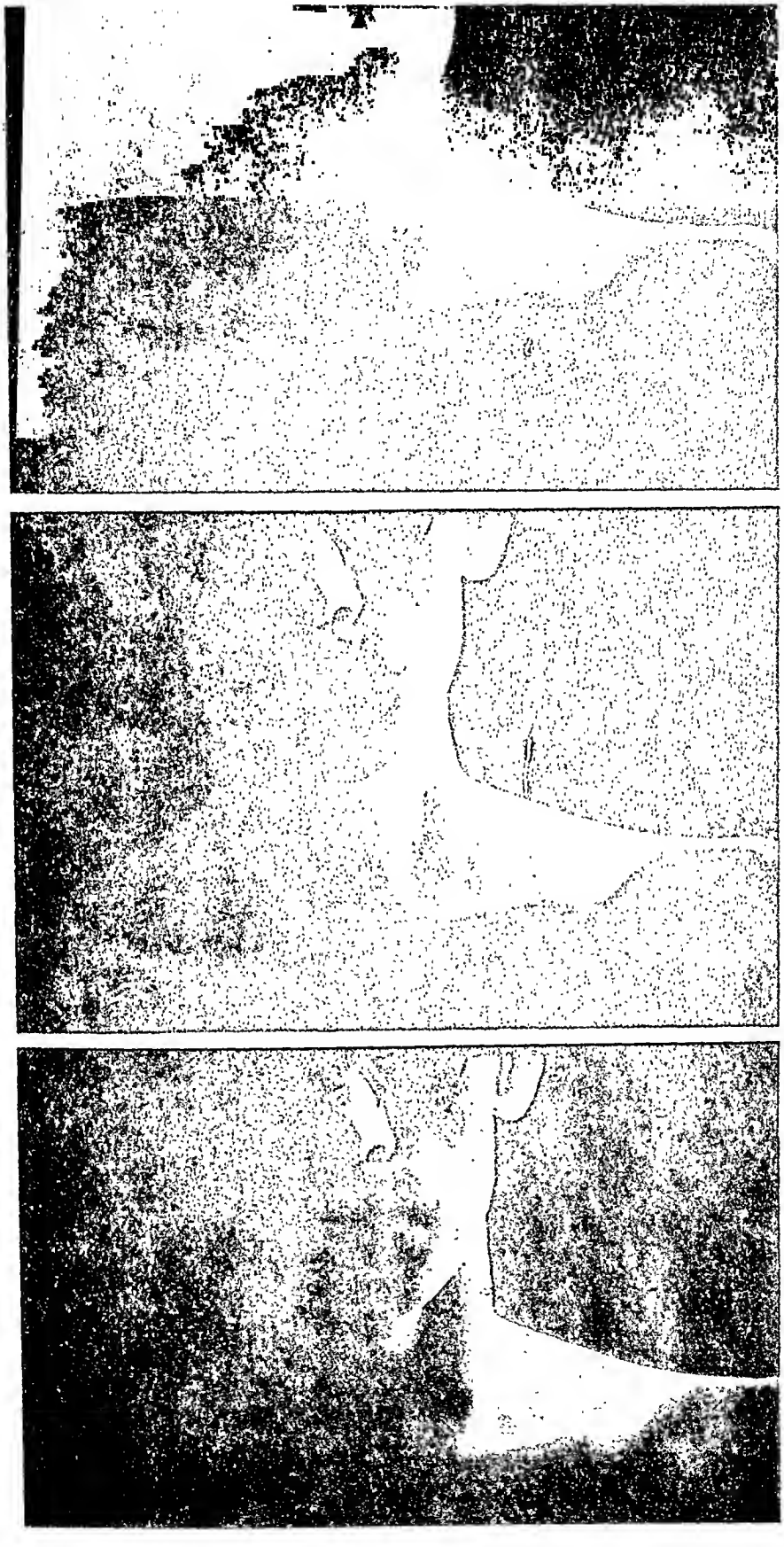


FIG. 2.—Case 3. (A), (B), (C) Sequential exposures taken from a moving picture film of the systolic deep jugular pulse of a young man with tricuspid stenosis: recorded in the sitting position. Early diastole in A, full systole in C, and midway in B.

majority of Dressler and Fiseher's cases. It was present in 7 of the 12 eases that we have ourselves examined elinieally.*

Aurieular fibrillation and polyeythaemia oeeur just as frequently in eases of pure mitral valve disease, espeeially the so-ealled " tight type," as in tricuspid stenosis. There is no evidenee in the group of eases here reported that pulmonary infarets are more frequent with tricuspid stenosis than in mitral stenosis alone.

No diagnostie signifieanee can be attaehed to the electroeardiogram.

We have estimated the *venous blood pressures* and *circulation rates* in seven of these patients. All the eases, although ambulatory and eomparatively well, gave readings between 19 and 27 cm. of water (method of Burwell *et al.*). This has been noted in the absenee of œdema, eonstrictive pericarditis, and mediastinal obstruction on several oeeasions (e.g. Friedlander and Kerr, 1936; Altsehule and Blumgart, 1937) and should be taken as a strong diagnostie point in favour of trieuspid stenosis. The cireulation times were all markedly prolonged, the right heart times averaging 20 seeonds (ether method) against a normal average of 6 seeonds.

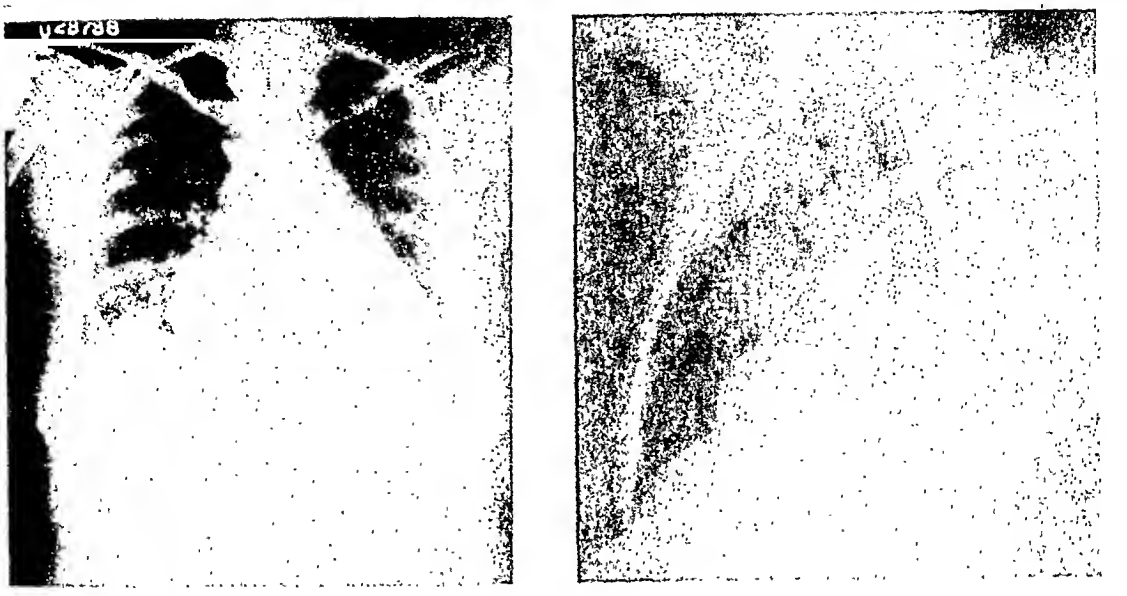
Dressler and Fiseher emphasized as an important diagnostie pointer the presenee of *marked enlargement of the heart to the right by X-ray* especially when assoeiated with absenee of pulmonary eongestion at the hilus of the lung.

Lian and Marchel (1936) drew attention to the *deviation of the œsophagus to the left* in the presenee of marked enlargement of the heart to the right. They suggested that this finding, while not pathognomonie of trieuspid stenosis, indieates enlargement of the right auriele and should lead to the suspicion of trieuspid stenosis. We have found in 4 of the eases here reported that the œsophagus is deviated to the left and in other instanees appears to travel down the front of thc spinal column in the midline. Certainly the incidenee of this left deviation of the œsophagus in our small group of cases warrants some eonsideration being paid to this finding (Fig. 3).

Castex, Battro, and Quirno (1939) reported two cases of tricuspid disease diagnosed during life. Kymograms of both patients suggested the diagnosis of trieuspid regurgitation by the presence of systolic pulsation in the right auricle and in the dilated superior vena cava.

We are herewith presenting the histories and essential findings in 17 of our cases, the first 3 in some detail as classical examples of the eondition and the last 14 in brief. Details are summarized in the table on p. 157. In the 217 autopsies of patients with rheumatic hearts already referred to, there were 5

* An interesting possible but doubtless very rare explanation for a middiastolic murmur at the lower end of the sternum, not transmitted from the apex and not due to organic tricuspid stenosis, is a mechanism in the right ventricle similar to that in the left ventricle which causes the Austin Flint murmur. namely, pulmonary regurgitation with dilated right ventricular cavity. It happens that recently (December 1939) one of us (P. D. W.) has encountered such a case, a patient in failure with marked mitral stenosis, functional pulmonary regurgitation giving rise to a Graham Steell murmur, and a well marked localized middiastolic rumble in the 4th intercostal space at the left border of the sternum just below and distinctly different and separate from the pulmonary systolic murmur. Tricuspid stenosis was diagnosed antemortem on this basis but not found at autopsy, which disclosed marked mitral stenosis, dilated partially thrombosed pulmonary artery and left auricle, and dilated right ventricle.



A B

FIG. 3.—(A) Antero-posterior X-ray view of the heart shadow of case of mitral and tricuspid stenosis showing barium-filled œsophagus deviated to the left.
(B) Left (II) oblique view of same case.

who had marked or clinically " pure " tricuspid stenosis, and 25 others with slight to moderate tricuspid stenosis, making a total of 30 cases.

CASE REPORTS

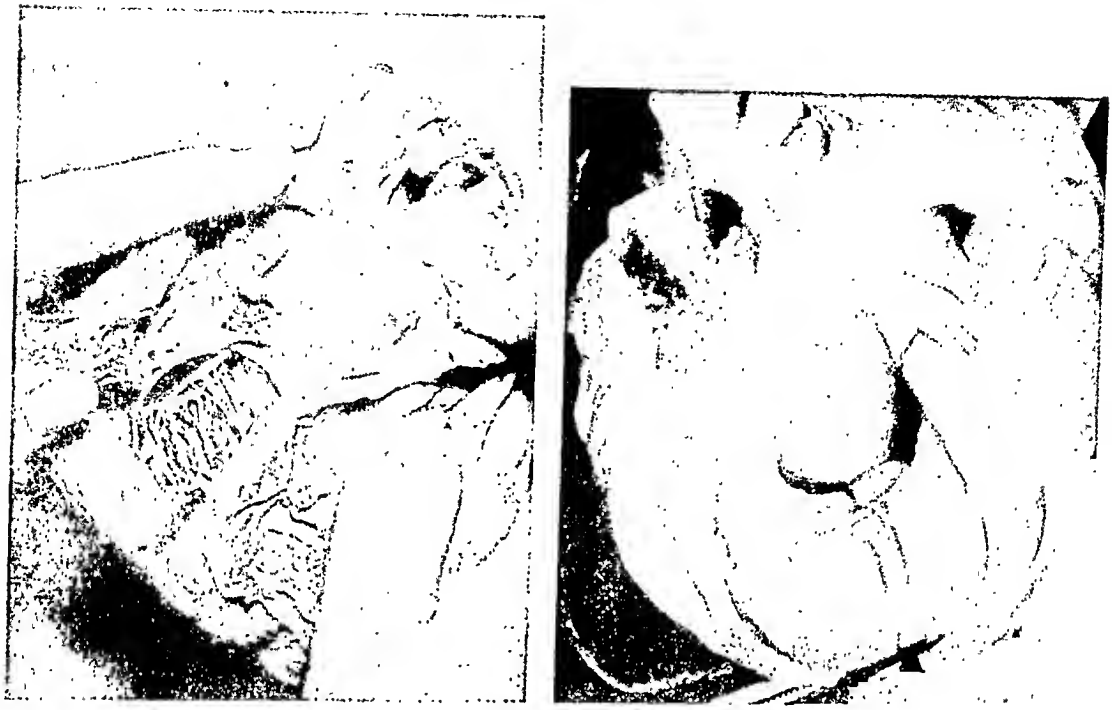
Case 1, female, aged 54 years. An attack of rheumatism at the age of 32 kept her in bed a short time, but she was back at work within three weeks. She first attended Massachusetts General Hospital in December 1935, for abdominal swelling of 18 months' duration. Mitral, tricuspid, and aortic stenosis and regurgitation were diagnosed. Since then she had carried on her housework and had entered the hospital every two or three weeks for abdominal paracentesis and occasional doses of salyrgan intravenously. Her condition remained fairly constant for the three years that she was under observation. She never used more than one pillow at night although the veins of the neck, forehead, and arms were remarkably distended when she lay down. She was slightly cyanosed and slightly icteric. The neck veins showed a systolic deep jugular pulsation extending to the angle of the jaw and easily obliterated by light pressure over the jugular bulb at the base of the neck. There was no engorgement of the superficial veins. Venous pressure was 26 cm. water. Circulation time: ether, 20 seconds (normal 5–10); and saccharin, 50 seconds (normal 15–25).

The heart was enlarged both to right and left and the œsophagus was deviated in its lower half to the left of the vertebral column. B.P., 115/85 mm. On auscultation there were systolic and mid-diastolic murmurs at the apex, and a loud aortic systolic murmur with a palpable thrill at the base, but no tricuspid murmur could be defined. EC., auricular fibrillation with moderate right axis deviation, slight slurring of the QRS waves, and " digitalis " T waves.

She was admitted to the hospital for the last time after a cerebral vascular accident and died a few days later in April 1939.

Autopsy.—The superior and inferior vena cavæ were much dilated, measuring 2·8 and 4 cm. respectively in diameter. The heart weighed 410 g. The right auricle

was much dilated and its walls hypertrophied. The cardiac apex was formed by the large right ventricle although the walls were not thicker than those of a normal right ventricle. The tricuspid valve admitted two fingers only and measured 10·5 cm. in circumference (Fig. 4A); all the leaflets were thickened and fused to form a slightly



A B

FIG. 4.—Case 1. (A) Markedly stenosed (button-hole) tricuspid valve seen from below, in a case of chronic rheumatic heart disease.
(B) Stenosed mitral valve seen from above, in the same case.

nodular band 12–13 mm. in width; the chordæ were not appreciably thickened. The left auricle was also much dilated, approximating in size that of the right. The mitral valve was of the fish mouth type, 6 cm. in circumference but with remarkably narrowed and rigid fused cusps and an opening approximately 2·5 by 0·5 cm. (Fig. 4B). The aortic valve was approximately 7 cm. in circumference, with fusion of the valve cusps and poor approximation. The liver was enlarged and showed cirrhosis which was thought to be cardiac in origin.

Case 2, female, aged 49. No history of joint pains, rheumatic fever, chorea, or scarlet fever during childhood. At the age of 14, she had a chest cold which confined her to bed for a fortnight and left her very weak for some months. She was, however, able to play games actively as a child. At the age of 22 she began to notice some undue shortness of breath while doing heavy housework, and began to complain of attacks of praecordial pain which have been present more or less ever since. At the age of 27, she was rejected for life insurance owing to a murmur in her heart, of which she had been unaware. At 43 years she had some signs of congestive failure which cleared up but have recurred from time to time ever since. The following year she was admitted to the hospital with slight congestive signs and menorrhagia due to fibroids. She was digitalized and was able to continue her work in the household and at a sewing centre. A diagnosis of tricuspid stenosis was queried. At the age of 47, she was again admitted with abdominal swelling of two years' duration and examination at that time showed cyanotic lips, malar flush, distension of the neck veins, markedly engorged

TABLE SHOWING IMPORTANT FINDINGS IN 17 CASES OF TRICUSPID STENOSIS

	*Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9	*Case 10	Case 11	Case 12	*Case 13	*Case 14	*Case 15	*Case 16	*Case 17
Age	54	49	40	54	60	36	57	50	39	34	58	29	21	41	42	30	41
Sex	F.	F.	M.	M.	F.	F.	M.	M.	F.	F.	M.	F.	M.	F.	F.	F.	F.
Rheumatic fever	+	0	0	+	+	+	0	+	+	+	+	+	+	0	?	0	0
Chorea	0	0	0	0	0	0	0	0	0	0	0	?	+	+	0	0	+
Duration of symptoms (in years)	5½	6	8	?	10	6	3	2	5	1½	4	?	+	7	?	2½	5
Cyanosis	sl.	sl.	+	sl.	sl.	sl.	0	0	sl.	sl.	0	sl.	+	+	+	sl.	+
Jaundice	sl.	0	0	0	sl.	sl.	0	0	sl.	sl.	0	0	0	0	0	0	0
Systolic deep jugular pulsation	+ +	+	+ +	+	+	+	+	+	+	+	+	+	+	—	—	0	+
Enlargement of liver	+ +	+	+	+	+	+	+	+	+	+	+	+	+	0	+	+	+
Pulsation of liver	+	+	+	+	+	+	+	+	+	+	0	+	+	0	+	+	+
Ascites	+ +	0	+ +	0	+	+	+	+	+	+	+	+	+	0	+	+	0
Diastolic murmur localized at lower end of sternum	0	+	+	+	0	0	+	0	0	+	+	+	0	0	0	—	+
Enlarged right heart	+	+	+	+	+	+	+	+	+	—	—	+	—	+	+	—	+
Deviation of œsophagus to left of midsternum (X-ray)	+	mid linc.	+		—	+	+	—	mid line.	-	—	—	—	—	—	—	—
Arterial pressure (mm. mercury) systolic	115	150	100	150	235	120	130	120	110	135	120	120	140	115	150	120	125
diastolic	85	80	70	80	100	80	80	90	70	80	90	70	55	80	80	75	85
Venous pressure (cm. water)	26	22	24	22	21	—	—	19	24	—	—	—	—	—	—	—	—
Circulation time (sec.); saccharin (arm to tongue)	50	30	—	45	44	—	—	60	44	—	—	—	—	—	—	—	—
Circulation time (sec.); ether (arm to lungs)	20	15	19	20	15	—	—	—	20	—	—	—	—	—	—	—	—
Auricular fibrillation	+	+	+	+	+	+	+	0	+	+	+	+	+	0	0	+	0

The last 5 cases (Nos. 13–17 inclusive) presented marked tricuspid stenosis at autopsy, as did also Case 10. The first 12 cases were carefully studied during life by ourselves.

The cases were comprised of 6 males and 11 females, whose ages ranged from 21 to 60 with an average of 43 years : 4 had no history of rheumatism, and 2 had had chorea only.

liver, palpable spleen, heart enlarged to the left, irregular rhythm, and systolic and diastolic murmurs at the apex. Over the next two years the enlargement of the liver was found constantly.

On examination at present her condition is good. She is able to do her housework and carries on with her sewing work. She has deep and superficial systolic pulsation in the neck veins and is a little cyanosed in lips and finger tips.

The heart is enlarged by X-ray to both right and left, but the lung hilar shadows are not strikingly abnormal. The heart is "mitral" in shape. The œsophagus runs down the front of the vertebral column. On auscultation there are systolic and mid-diastolic murmurs at the apex, and localized systolic and faint diastolic murmurs, separate and distinct, at the lower end of the sternum. The sounds at the aortic area are quite clear. The liver is enlarged two fingers' breadth below the costal margin, and pulsates with systole. B.P., 140/80 mm. EC., auricular fibrillation, no abnormal axis deviation, and digitalis T waves. Venous pressure 21–24 cm. water. Circulation time: ether 15 seconds (normal 5–10); lobeline over 30 seconds (normal 15–20).*

Case 3, male, aged 40 years. First seen by us at the age of 21, following rejection for life insurance. He had run as a member of his high school team and had been apparently quite healthy until one year previously when he had some mild rheumatic pains and some paroxysms of tachycardia. At that time he had a normal sized heart, a blood pressure of 90/65, an accentuated and reduplicated pulmonary second sound, a blowing watery systolic murmur nearer the sternum than the apex, and a short early diastolic murmur in the second and third left interspaces, while the EC. showed normal rhythm with probable early intraventricular block. For the next ten years he was fairly well, working hard, until in 1931 at the age of 32 he developed auricular fibrillation and congestive failure. He made a good recovery, and in 1934 visible venous pulsation in the neck, an enlarged and pulsating liver, and a very large heart were found; in spite of this he was able to walk five miles a day without undue discomfort. The diagnosis of tricuspid stenosis was then queried. In 1935 a note was made that the mid-diastolic murmur was louder at the lower end of the sternum than at the apex. At the end of 1936 ascites began to be a prominent symptom and necessitated paracentesis every ten to fourteen days, 10–12 litres being withdrawn each time. In 1937 his activities were extremely limited by fatigue and dyspnœa, and a prognosis of only a few months of life was given. However, over the past two years his condition has not grown any worse and at present he spends his time resting, walking about the house, and going out for car rides.

On examination his facial appearance is evident in Fig. 2. He shows slight cyanosis, emaciated musculature, a prominent abdomen, and marked systolic, deep jugular pulsation in the neck veins (Fig. 2 A and B); on auscultation there are systolic and diastolic murmurs at the apex, and at the lower end of the sternum there are two other distinct murmurs; the liver is enlarged and pulsating, and there is marked ascites. B.P. 100/70. X-ray examinations, over the years from 1931 to the present, have revealed a steadily increasing heart size, so that now the shadow of the right heart border touches that of the right chest wall. The œsophagus is deviated slightly to the left in the lower half of its course through the thorax. EC., auricular fibrillation and intraventricular block of the right branch type. Vital capacity in 1931, 3550 c.c.; in 1939, only 1900 c.c. The venous pressure is 23·5–24·5 cm. water. Circulation rate: ether time 19 seconds (normal 5–10).

Case 4, male, aged 54 years. Rheumatic fever at the age of 34, in bed 14 weeks. Worked steadily thereafter as a mechanic. Examined after a transient attack of blurring of vision and weakness, there was slight cyanosis, systolic deep jugular pulsation, a slightly enlarged liver with definite expansile pulsation, localized systolic and diastolic murmurs at the lower end of the sternum, and in addition the murmurs diagnostic of mitral and aortic stenosis and regurgitation, and auricular fibrillation. X-ray showed enlargement of the heart to right and left. He is still working as a mechanic.

* For later notes and autopsy see Addendum on p. 165.

Stenosis and regurgitation of the mitral, aortic, and tricuspid valves was diagnosed. Venous pressure was 22 cm. water. Circulation rates: ether time, 20 seconds; saccharin time, 45 seconds. A point of special interest in this case, besides that of his relatively good condition, is that his systolic jugular pulsation was mistaken for a carotid pulse in the medical clinic.

Case 5, female, aged 60 years. Rheumatic fever at the age of 40. She has had twelve children and two miscarriages. She was first seen for her heart trouble because of attacks of tachycardia and fibrillation at the age of 45. First admitted to hospital for congestive failure at the onset of permanent fibrillation ten years ago, at the age of 50 years. At that time she had an enlarged and pulsating liver and ascites and one of us questioned the diagnosis of tricuspid stenosis. For the past ten years she has been much the same, becoming dyspnœic on slight exertion and presenting on X-ray examination a heart enlarged both to right and left, and on physical examination an enlarged and pulsating liver. She lives alone on a hill and is able to do her housework and some shopping and comes to the cardiac clinic once a month.

At present she is slightly cyanosed with systolic pulsation of the neck veins, which has been present for at least one year. Although the liver is large and pulsating, there is no ascites or œdema of the ankles. There is no localized tricuspid murmur. EC., auricular fibrillation and intraventricular block. B.P., 235/100. A diagnosis of mitral and aortic stenosis and regurgitation, tricuspid regurgitation and probable tricuspid stenosis, and hypertension has been made. Venous pressure 21 cm. water. Circulation time: ether, 15 seconds; saccharin, 44 seconds.

Case 6, female, aged 36. First attack of rheumatic fever at the age of 24 and a second attack two years later. She was admitted to the hospital in congestive failure in 1933 and for this a total thyroidectomy was performed. Since then she has been troubled with symptoms of myxœdema and hypo-parathyroidism, and was always on the edge of congestive failure with repeated attacks of ascites and always with an enlarged pulsating liver. A diagnosis of mitral stenosis and regurgitation, tricuspid regurgitation and probable tricuspid stenosis, and aortic stenosis has been made.

Autopsy in January 1941 confirmed the clinical diagnosis of rheumatic heart disease with pancarditis, panvalvulitis, and pericarditis, chronic; cardiac hypertrophy and dilatation; mitral, aortic, and tricuspid stenosis and regurgitation, slight œdema, slight ascites, slight bilateral hydrothorax, pulmonary congestion, and confluent bronchopneumonia of the right upper lobe and right lower lobe.

Case 7, male, aged 57. At the age of 13 years his mother told him that he had valvular heart disease, but he had no definite history of rheumatic fever. His presenting symptoms on admission to the hospital were œdema of the ankles and dyspnœa of three years' duration and abdominal swelling of one year's duration. On the basis of his liver enlargement and ascites, systolic jugular pulsation, enlargement of the heart to right and left, and a localized diastolic murmur, a diagnosis of tricuspid stenosis, in addition to mitral stenosis, was made. He responded well to digitalis, and is now ambulatory and comparatively well though somewhat limited in his activities, twelve months after discharge from hospital.

Case 8, male, aged 50. Rheumatic fever at the age of 17. Otherwise well until two years ago when he had an attack of swelling of the joints, following which he got increasingly short of breath, and his abdomen swelled. A diagnosis of tricuspid stenosis and regurgitation was made on the basis of the history, the marked systolic jugular pulsation, a large pulsating liver that was not tender, ascites, some enlargement of the heart to the right, and a localized systolic murmur at the lower end of the sternum, in addition to the signs of mitral and aortic valve lesions. At present, six months later, he is able to help in the house, do light gardening, and keep his chickens, but he is not able to perform any strenuous work. Venous pressure, 19 cm. water. Circulation rate, using decholin, 60 seconds.

Case 9, female, aged 39. Repeated attacks of polyarthritis from the age of 16 to 34, although she never took any prolonged rest in bed and was doing fairly heavy work

as a housemaid for most of this time. Four years ago admitted to the hospital in congestive failure from which she made a good recovery; systolic jugular pulsation was noted on this occasion. Her last admission was precipitated by excessive exertion on coming to the city every day to go to a sewing centre.

A diagnosis of tricuspid stenosis and regurgitation was made on the basis of the history, the jugular pulsation, a pulsating enlarged liver, a localized systolic murmur at the lower end of the sternum, and X-ray enlargement to the right and left with the œsophagus passing down the front of the vertebral column. The venous pressure was 24 cm. water, and circulation rates were prolonged: with ether, 20 seconds, and with saccharin, 44 seconds. She is ambulatory, but restricted in her activities.

Case 10, female, aged 34 years. Rheumatic fever at the age of 7 and again at 13 with pericarditis. In bed for two years from the age of 20 to 22, and then able to work for eleven years as a stenographer. She was admitted to the hospital with recurrent rheumatism, auricular fibrillation, and congestive failure, twenty months before death. Ascites and œdema and the enlarged pulsating liver showed little variation except for temporarily yielding to diuretics. On account of the persistence of the failure and the pulsation of the liver and in the neck, and a localized diastolic murmur at the lower end and to the left of the sternum, a diagnosis of tricuspid stenosis in addition to mitral and aortic valve disease was made. She died suddenly.

Autopsy showed marked mitral, tricuspid, and aortic stenosis.

Case 11, male, aged 58. Well and active as a youth. Rheumatic fever, at the age of 37, kept him out of work for 4 years, and affected his heart. He felt well, however, thereafter for 13 years. He has had dyspnœa for 4 years and swelling of his abdomen, for the past 2 years, for which he has had to have abdominal paracentesis every few weeks.

A diagnosis of tricuspid stenosis in addition to mitral stenosis was made on the basis of the history of systolic jugular pulsation, an enlarged liver with ascites, a large heart, and localized systolic and diastolic murmurs at the lower end of the sternum.

Case 12, female, aged 29. Rheumatic fever with joint pains; at the age of 7, chorea for six weeks, recurring each winter until the age of 13 when a heart lesion was first diagnosed. Married at the age of 18, there was a normal pregnancy and delivery at 22. The auricles began to fibrillate at 23 and she developed congestive failure. Since then marked limitation of activities, with three attacks of congestive failure and probable rheumatic fever. For the past ten months she has had ascites and œdema of the legs and relatively little dyspnœa, and has been living a bed-and-chair existence.

A diagnosis of tricuspid stenosis has been made upon the history suggestive of long-standing right heart failure, a large pulsating liver, a localized diastolic murmur at the lower end of the sternum, marked enlargement of the heart to the right by X-ray, and slight systolic deep jugular pulsation.

Case 13, male, aged 21, negro. Rheumatic fever at the age of 6; no recurrences. His activity was not restricted. He played games, graduated from high school, and worked as a day labourer until he developed acute rheumatic fever two months previous to his admission to hospital. He was admitted with tremendous œdema of the legs and abdomen. Fibrillation of the auricles was present.

Autopsy showed marked stenosis of mitral, aortic, and tricuspid valves.

Case 14, female, aged 41. Chorea at 12 and 14. She married and had five children, the last at the age of 24 years without any difficulties. At 34, she was admitted to the hospital owing to increasing shortness of breath and attacks of pulmonary œdema and a three months' pregnancy which was terminated. X-ray showed enlargement of the heart to the right. The cardiac rhythm was regular. She was able to do heavy housework with the aid of full digitalization, until two weeks before her death from cerebral embolism.

Autopsy showed chronic rheumatic endocarditis, with marked stenosis of both mitral and tricuspid valves, cardiac hypertrophy, embolism and thrombosis to the bifurcation of the abdominal aorta, both external and internal iliac, and both renal arteries, embolus at bifurcation of the basilar artery with occlusion of postero-median

ganglionic branches, infarction of the spleen and both kidneys, pulmonary congestion, and cholelithiasis.

Case 15, female, aged 42. Whooping cough at 5, pneumonia at 9 and 12, and also " rheumatism " in childhood. She had suffered from ill health most of her life, with cough, sputum, and hemoptysis, thought to be due entirely to bronchiectasis. Her third hospital admission found her with marked congestion (anasarca); she died at this time.

Autopsy showed tightly stenosed mitral and tricuspid valves.

Case 16, female, aged 30. At 16, because a rapid regular cardiac impulse was noticeable on the chest wall, she was put to bed for one month, although she had no symptoms at all. After this she resumed her usual active life. At the age of 22 she had paroxysmal tachycardia but was able to play tennis and dance energetically. Two and a half years before death she developed generalized œdema of the extremities, chest, back, and face, with ascites, for which she was bedridden. She was not relieved by diuretin or digitalis.

Autopsy revealed mitral and tricuspid stenosis and active rheumatism.

Case 17, female, aged 41. Chorea at 12 and 14, and a syncopal attack at 17, following which valvular disease was discovered. At 27 she collapsed while nursing and from then onwards she was much limited by dyspnœa. Ten years ago (at 31) œdema of her ankles set in and marked cyanosis appeared two years ago. Following her mother's death she became psychopathic and was admitted to the hospital. At this time her lungs were clear, but she showed a slightly enlarged liver, ascites, and slight œdema of the legs. She grew worse and died.

Autopsy showed marked stenosis of aortic, mitral, and tricuspid valves, the tricuspid valve barely admitting the tip of the finger.

Discussion

Tricuspid regurgitation as evidenced by pulsating neck veins, a distended and pulsating liver, tricuspid murmurs, and in some cases by the absence of any respiratory distress in spite of marked ascites and œdema, is not uncommon in children suffering from rheumatic fever. The signs may persist for some months and only disappear with the disappearance of the rheumatic fever and the recovery of normal function of the heart muscle. It is therefore unwise, save in exceptional cases, to make a diagnosis of tricuspid valve disease in the first two decades of life, or in a patient within five or six years of the onset of his rheumatic fever.

Cases presenting the full tricuspid syndrome of ascites, œdema, pulsating neck veins, and surprising functional ability have been reported, in whom autopsy has revealed only an irreversible stretching of the valve and no endocarditis (Fischer, 1928, Holzman, 1932, and White and Cooke, 1939). There appears to be no method of avoiding this diagnostic pitfall. The stretching of the tricuspid ring, which occurs during failure but may persist even after the right ventricle has recovered in large part or wholly, presents the chief diagnostic difficulty. This stretching of the valve ring may be present in a case of isolated mitral stenosis, in which instance the full tricuspid syndrome will be simulated.

Some cases of long-standing systemic arterial hypertension develop this " tricuspid syndrome " over the last three to four years of their life. At autopsy the only abnormality is some dilatation of the tricuspid valve ring with the production of incompetence.

Finally, of course, cases of constrictive pericarditis must be distinguished. The absence of heart murmurs and of any more than the slightest enlargement of the heart should be sufficient to distinguish these cases from rheumatic heart disease.

For interest we determined the average age at death of 160 consecutive autopsied cases of rheumatic heart disease, excluding those with tricuspid involvement. This proved to be 43·5 years. The same determination was carried out in the series of 30 autopsied cases of tricuspid valve disease referred to earlier in this paper with the finding of 23·4 years; however, the average in our series of 17 cases whose histories we have presented was 43 years, with several patients still alive.

Gross, Kugel, and Rothschild (1934) in careful investigations showed that in the first five decades of life, lesions indicative of active rheumatism were present in over 80 per cent of cases with rheumatic heart disease dying of congestive failure. As patients grow older the frequency of attacks of rheumatic fever tends to grow less. In the young age group the attacks are frequent. In the first three decades, therefore, it is probably true to say that it is the state of the myocardium that plays the dominant part in the survival of the patient, while afterwards, the mechanical factors produced by the valve lesions play an increasingly important role in determining whether the heart can continue to function adequately. The whole group can consequently be divided into two, a young group in the first three decades of life and an old group. In the young group the greatest number of autopsies will occur in a general hospital as the patients are often acutely ill with rheumatic fever. The more severe the infection, the more likelihood there is that the tricuspid valve is affected. If, therefore, one can make a diagnosis of tricuspid stenosis in this first group, it indicates an extremely grave prognosis as to future life.

In the older group, the mechanical factors produced by the valve deformity begin to play an important role. The safety valve function has been recognized for many years, acting either by regurgitation or stenosis in preventing the dangerous distention of the right ventricle or of the lung capillaries that attends marked mitral stenosis. This function is very well illustrated by *Case* 1, a patient who was able to carry on with her household tasks in spite of such marked mitral and tricuspid stenosis as is shown in the illustration (Fig. 4 A and B). Her venous pressure was 21 cm. of water, and she always insisted on sleeping with one pillow only, an observation that is not in keeping with Altschule and Blumgart's contention that orthopnœa is closely related to a raised venous pressure.

The importance of recognizing tricuspid valve disease in this older group is, again, but for a different reason, in establishing the correct prognosis. As has already been stressed these patients, although they will probably die at an earlier age than similar patients without the tricuspid valve affected, are able for some years to live a sheltered and useful life, although constantly presenting signs and symptoms that would lead one to expect a much earlier demise.

Thus, although well-marked tricuspid valve disease (stenosis) is found in

cases of rheumatic heart disease who live somewhat shorter lives than do those without tricuspid valve disease, this lesion is found in those cases who survive the longest (a matter of several years at least, as a rule) after the systemic veins (including the jugulars) and the liver become permanently engorged, with the appearance of ascites.

The realization of the true state of affairs in these older cases indicates the correct line of treatment. The chief complaint is usually recurrent or persistent ascites and œdema. Fluids must therefore be restricted and carefully balanced with the urinary output, a procedure these patients perform for themselves. Mercurial diuretics at regular intervals, or from time to time when required, give good results. Digitalis may or may not be indicated, depending chiefly on the heart rate when auricular fibrillation is present; as a rule it is necessary. Occasionally these measures are not sufficient and then abdominal paracentesis may be carried out when needed. It is unfortunately still true in many places that the auscultation of murmurs indicative of rheumatic heart disease in these patients leads automatically to the administration of large doses of sodium salicylate and sodium bicarbonate. Such drugs in these patients can only increase the patients' discomfort by causing increased water retention. For this reason, also, diets should be kept as low as possible in salt, and frequent saline diuretics such as those frequently advertised in the press for the production of a feeling of " well being " should be avoided.

It will be noted that the cases we are reporting are, with two exceptions, in the fourth, fifth, and sixth decades. The antecedent histories in all these cases are similar—the usual story being: (1) a single attack of rheumatic fever, leaving no demonstrable lesions until some years later when heart disease is discovered on routine examination; (2) attacks of chorea without any apparent heart involvement; or (3) isolated attacks of rheumatic fever in the fourth or fifth decade. In none of these cases was there a period of chronic ill health which is the commonest course for rheumatic fever to follow. In the past histories this group is very similar to a series with so-called " pure " mitral stenosis reported by Walsh, Bland, and Jones (1940). They found that patients who had had a single attack of rheumatic fever in childhood without any residual heart damage or those who had no definite previous rheumatic symptoms frequently appeared later with well marked mitral stenosis. A suggested explanation of this marked stenosis is that there never has been any great dilatation of the heart and that therefore gradual and progressive fibrosis of the valve has been allowed to proceed undisturbed during a long continued active rheumatic infection that has largely passed unnoticed.

Summary and Conclusions

Between 1920 and 1937 there were 217 cases of rheumatic heart disease occurring in 4300 autopsies at the Massachusetts General Hospital. In 47 of these the tricuspid valve was affected, but in only 30 was tricuspid stenosis thought to be of sufficient degree to be of clinical significance.

In addition 12 cases of tricuspid valve stenosis have been examined

clinically by the authors during the past three years including 3 cases that came to autopsy.

There were 21 males and 21 females in the combined groups of 33 autopsied and 9 clinical cases.

The ages at death varied between 10 and 59 years, and the average age for the 30 cases with autopsies was 23 years. The average age at death of 160 cases of rheumatic heart disease in the same hospital was 42 years.

The cases of tricuspid valve disease may be divided into two groups: a young group in the first three decades dying of rheumatic fever, and an older group in whom the mechanical factors induced by the lesions played an increasingly important part.

The symptoms in the younger group were almost indistinguishable from those of rheumatic fever: the older group was characterized by the relatively long survival after the appearance of congestive symptoms and signs indicative in most other circulatory disorders of death in the near future.

The diagnosis of tricuspid disease in the young group indicates serious involvement of the myocardium and a poor prognosis; in the older group owing to the " safety valve " function of the tricuspid valve, the patients may live many years providing there is no recurrence of severe rheumatic fever.

The diagnosis of tricuspid disease is difficult, but when due attention is paid to the history, clinical examination of the patient, and X-ray of the heart, the diagnosis should be made more frequently. No one sign is pathognomonic, but in the order of importance the clues may be listed as follows (their chief value lies in combination): a mid-diastolic murmur localized over the tricuspid area, chronic and well-marked systolic pulsation of the deep jugular veins, ascites in the absence of lung congestion, enlargement of the heart shadow to the right, deviation of the œsophagus to the left, cyanosis and sometimes jaundice, enlarged liver with or without pulsation, persistently raised venous pressure, and prolonged right heart circulation time. The chief reason that the diagnosis is not made more often is that these clues and signs are not looked for.

The diagnosis of tricuspid disease is important as an aid in the more accurate determination of prognosis and treatment.

Addendum

Later Notes of Case 2.

A steady increase of dyspnœa, œdema, and ascites over a period of four months brought her into the hospital again on June 20, 1941, with marked anasarca, and she died two days later. Post-mortem examination showed a moderately hypertrophied heart with marked enlargement of the right ventricle which formed a large portion of the apex of the heart. Weight 450 grams. Right ventricle wall thickness was 5 mm. Mitral valve stenosed, buttonhole type; the circumference was 8 cm.; small thrombus in the left auricular appendage. Aortic valve very slightly involved by rheumatic adherence of the cusps. Aorta smooth. Pulmonary valve normal. Right auricle very large. Tricuspid valve moderately stenosed with shortened chordæ tendineæ. No thrombi in right auricle. Small recent pulmonary embolus and infarct (probably the immediate cause of death). Liver cirrhotic and congested. Kidney congested. Spleen normal.

References

Altschule, M. D., and Blumgart, H. L. (1937). *Amer. Heart J.*, **13**, 589.
Bland, E. F., Jones, T. D., and White, P. D. (1935). *Ibid.*, **10**, 3.
Cabot, Richard (1926). *Facts on the Heart*, Philadelphia, pp. 159 and 173.
Castex, M. R., Battro, A., and Quirno, W. (1937). *Rev. Argent. Cardiol.*, **4**, 113.
Clements, A. B. (1935). *Amer. J. med. Sci.*, **190**, 389.
Coombs, C. (1924). *Rheumatic Heart Disease*, New York.
Dressler, W., and Fischer, R. (1929). *Klin. Wschr.*, **8**, 1269 and 1316; also *Z. Kreilssaufforsch*, **22**, 188 (1930).
Durozierz (1868). *Gazette des Hopitaux*, 310.
Fischer, R. (1928). *Wien, klin. Wschr.*, 19.
Friedlander, R. D., and Kerr, W. J. (1936). *Amer. Heart J.*, **11**, 357.
Herrick, J. B. (1897). *Boston med. and surg. Jour.*, **136**, 245.
Herrick, W. W. (1908). *Arch. intern. Med.*, **2**, 291.
Hirschfelder, A. (1910). *Diseases of the Heart and Aorta*, Philadelphia, p. 406.
Holzman, M. (1932). *Frsch. a. d. Geb. d. Rœntg.*, 46, 14.
Levine, S. A., and Thompson, W. P. (1937). *Amer. J. med. Sci.*, **193**, 4.
Lian, C., and Marchal, M. (1936). *Bull. Mem. Soc. méd. Hôp. Paris*, **52**, 954.
Libman, E. (1923). *Jour. Amer. med. Assoc.*, **80**, 813.
Lewis, T. (1933). *Diseases of the Heart*, New York, p. 141.
Mackenzie, J. (1892–3). *J. Path. and Bact.*, **1**, 53.
—— (1913). *Diseases of the Heart*, 3rd ed., Oxford University Press.
Osler, W., and Gibson, A. G. (1915). *Diseases of Valves of the Heart*, 2nd ed., *Modern Medicine*, Philadelphia. Lea and Febiger.
Rothschild, M. A., Kugel, M. A., and Gross, L. (1934). *Amer. Heart J.*, **9**, 586.
Strümpell, A., and Seyfarth, C. (1928). *Lehrbuch d. Inneren Krankheiten*, Leipzig.
Thayer, W. S. (1925). *Bull. Johns Hopkins Hosp.*, **36**, 99.
Tschilikin, W. I. (1930). *Z.f. Kreislauff.*, **32**, 177.
Von Glahn, W. C. (1927). *Arch. Path. & Lab. Med.*, **3**, 355.
Walsh, B. J., Bland, E. F., and Jones, T. D. (1940). *Arch. intern. Med.*, **65**, 321.
Wearn, J. T. (1936). "*Medical Papers.*" *Christian Birthday Volume*, pp. 60–5.
White, P. D., (1937). *Diseases of the Heart*, New York, 2nd ed., p. 453.
White, P. D., and Cooke, W. T. (1939). *Trans. Assoc. Amer. Phys.*, **54**, 199.
Zeisler, E. B. (1933). *Amer. Heart J.*, **8**, 697.

IDIOPATHIC CYSTIC MEDIAL NECROSIS OF THE AORTA

BY

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Cystic necrosis of the aortic media is recognized as a cause of dissecting aneurysm and of spontaneous rupture of the aorta. Its occurrence in association with aneurysmal dilatation of the unruptured aorta is sufficiently rare to warrant the following case being reported.

Clinical Report and Necropsy

A man, aged 36, attended the out-patient department of the Middlesex Hospital in February 1940. He had never had rheumatic fever, chorea, or syphilis. Ten years previously he had first noticed dyspnœa on exertion and had been told at the time by his doctor that he had heart disease. During 1938 and 1939 he had become increasingly short of breath on effort, and for several weeks prior to coming to hospital he had suffered from paroxysms of nocturnal dyspnœa with blood-stained expectoration.

On examination he was breathless and orthopnœic. The pulse was regular and collapsing; the brachial arteries normal; the blood pressure 150/60 mm. The apex beat was in the mid-axillary line; systolic pulsation was visible in the second and third right intercostal spaces near the sternum; and systolic and diastolic thrills were palpable in the same area. A loud blowing diastolic murmur was heard on the left of the sternum and at the apex. There were widespread râles throughout both lung fields, but signs of systemic congestion were absent; the cervical veins were not engorged, the liver was not enlarged, and there was no œdema. The Wassermann reaction was negative.

X-ray examination showed gross enlargement of the left ventricle, aneurysmal dilatation of the ascending aorta, and increased aortic pulsation (Fig. 1); there was no radiological evidence of mitral stenosis on screening. An electrocardiogram showed normal rhythm, with left axis deviation, a P–R interval of 0·20 sec., and inversion of the T waves in leads I and II.

The patient died in an attack of acute pulmonary œdema, four days after admission to hospital.

Necropsy.—(Permission was obtained for removal of the heart and lungs

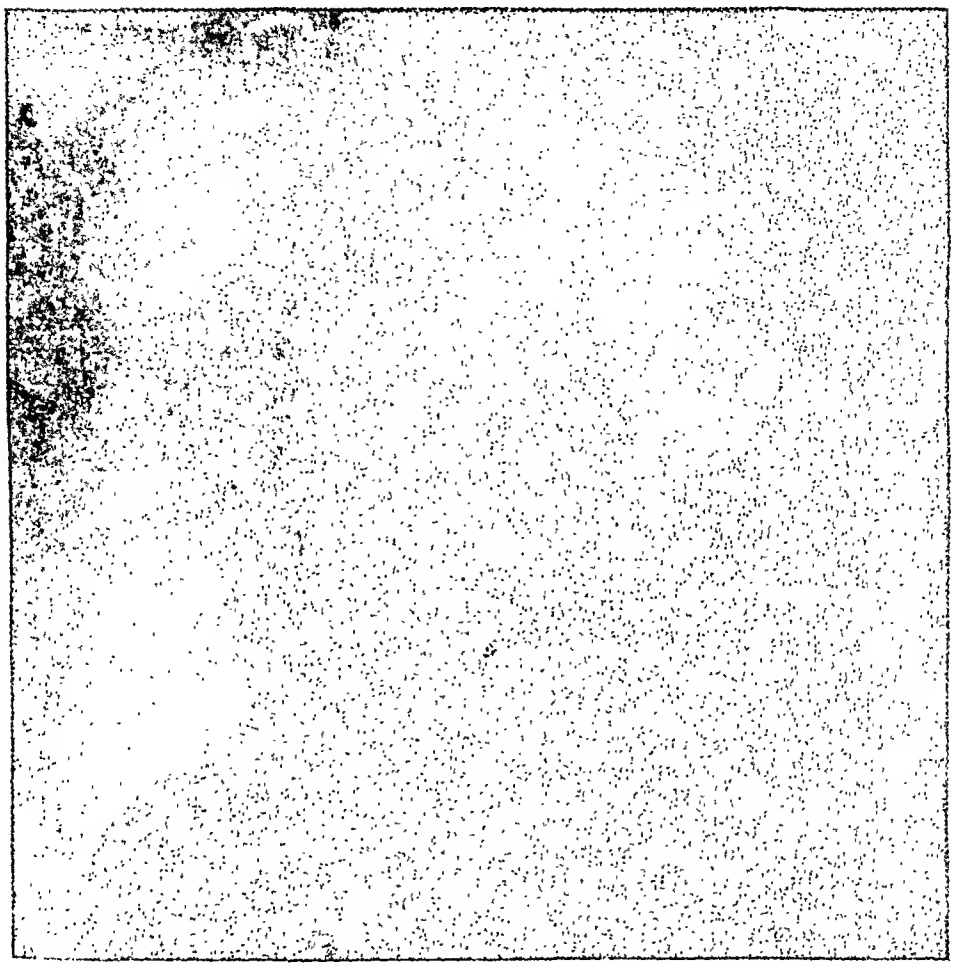

FIG. 1.—Radiograph showing aneurysmal dilatation of the ascending aorta and enlargement of the heart to the left.

only.) The heart weighed 27 oz. (765 g.). The left ventricle was both hypertrophied and dilated; the heart muscle was firm. The aortic ring was dilated, the valve cusps were thin and larger than normal, but appeared competent; the other valves were normal. The ascending aorta as far as the commencement of the innominate artery was uniformly dilated, measuring approximately 6 cm. in diameter (Fig. 2). The wall of the aorta was slightly thinner than normal, and the intima was smooth. The coronary arteries were normal. Histological examination of the aorta showed cystic medial necrosis.

A histological report by Dr. R. W. Scarff, of the Bland Sutton Institute of Pathology, was as follows:—

" The main feature of sections (see Fig. 3), taken both at and below the lesion, is widespread degeneration of both muscular and elastic tissue with the formation of small cystic areas, containing mucoid material, which stains bluish with Mayer's hæmalum but does not give a positive muci-carmine stain. With Van Gieson's stain very little muscle can be found, and there is some fibrous tissue replacement, and no marked increase in the sub-endothelial fibrous

FIG. 2.—Photograph of the heart, post-mortem, showing a greatly dilated ascending aorta.

tissue. With Weigert's elastic stain there seems to be diminution in the elastic material, and complete absence of it in the extensive mucoid areas. In other parts of the section the elastic material appears as irregular short lengths of fibre which are fragmented; no internal or external lamellæ can be distinguished. The appearances are those of intense degeneration of musculo-elastic tissue with cystic areas and areas of fibrous replacement." (See Fig. 3.)

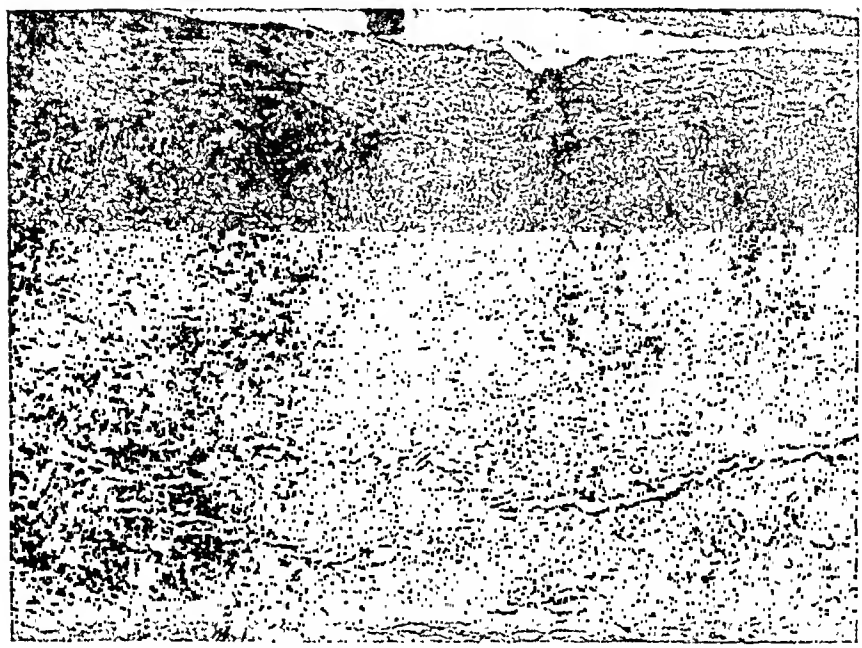

FIG. 3.—Section of the aorta showing areas of degeneration with cystic change. Magnification × 65.

DISCUSSION

The clinical picture was that of terminal left ventricular failure in a man, aged 36, with aortic incompetence and aneurysmal dilatation of the aorta. The radiological appearances were suggestive of a syphilitic ætiology, though the history of heart disease of ten years' duration and the negative Wassermann reaction were against this. Cystic medial necrosis was not suspected.

Rottino (1940) stated that only 2 cases of cystic medial necrosis in unruptured aortas had been reported. Signs of aortic incompetence due to dilatation of the aortic ring have been observed in dissecting aneurysm (Resnik and Keefer, 1925), and a case of medial necrosis was described by Roberts (1939) in a man, aged 33, with dilatation of the aorta, aortic incompetence, and congestive failure; death was due to spontaneous rupture of the aorta. At necropsy, the aortic ring was dilated, and section of the aorta showed medial necrosis, the valves being normal. Rottino (1939) reported the case of a woman. aged 70, in whom the ascending aorta was diffusely dilated and thin-walled, and macroscopically the intima simulated syphilitic aortitis, but there were no murmurs of aortic incompetence. Dilatation of the ascending aorta with aortic incompetence occurred in Harrison's case (1939), but as coarctation was also present it is difficult to assess the part played by medial necrosis in causing the dilatation.

Medial necrosis is a common finding in cases of spontaneous rupture of the aorta. Glendy, Castleman, and White (1937) found it in 8 of 19 cases of ruptured aorta, and Klotz and Simpson (1932) in all of 5 cases, the youngest being a woman, aged 23, who was pregnant. Moritz (1932), examining routine unselected necropsy material, found medial necrosis in 6 of 70 cases, and

Rottino (1939) found an even higher incidence—95 cases of medial degeneration in a total of 210, with cystic changes in 7 cases.

Since the first descriptions of cystic medial necrosis by Gsell (1928) and Erdheim (1929), detailed accounts of the pathology have been given by Moritz (1932) and Rottino (1939, 1940).

The most advanced changes occur in the ascending aorta, especially at its root just above the valves; this is also the site of election for spontaneous rupture. The ætiology of the condition is still unknown. It was first thought to be a degenerative process associated with old age, but subsequent reports have shown that it occurs not infrequently in young people. Toxæmia, nicotine, hyperadrenalism, and hypertension have all been mentioned as factors. It is generally agreed that syphilis plays no part.

It is evident from the reports cited that cystic medial necrosis of the aorta is by no means excessively rare, and that it may cause diffuse dilatation of the ascending aorta and aortic incompetence. It should therefore be considered in the differential diagnosis of unexplained dilatation of the aorta.

Summary

A case of idiopathic cystic medial necrosis of the aorta, without rupture, has been reported. The presenting signs were those of aneurysmal dilatation of the aorta with aortic incompetence and terminal left ventricular failure.

I have to thank Dr. G. E. S. Ward, Lieut.-Colonel Evan Bedford, and Dr. G. E. Beaumont for permission to publish this case, and Dr. R. W. Scarff for the histological report.

References

Erdheim, J. (1929). *Virchows Arch.*, **273**, 454.
Gsell, O. (1928). *Ibid.*, **270**, 1.
Glendy, R. F., Castleman, B., and White, P. D. (1937). *Amer. Heart J.*, **13**, 129.
Harrison, F. F. (1939). *Arch. Path.*, **27**, 742.
Klotz, O., and Simpson, W. (1932). *Amer. J. med. Sci.*, **184**, 455.
Moritz, A. R. (1932). *Amer. J. Path.*, **8**, 717.
Resnik, W. H., and Keefer, C. S. (1925). *J. Amer. med. Ass.*, **85**, 422.
Roberts, J. A. (1939). *Amer. Heart J.*, **18**, 188.
Rottino, A. (1939). *Arch. Path.*, **27**, 321.
—— (1940). *Ibid.*, **28**, 337.
—— (1940). *Amer. Heart J.*, **19**, 330.

THE ELECTROCARDIOGRAM OF THE STOKES-ADAMS ATTACK

BY

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The combination of a slow pulse with syncopal, epileptiform, or pseudo-apoplectic attacks was briefly mentioned by Morgagni in 1761; then it was more fully described by an Edinburgh physician, Spens (1793), and by Adams (1827) and Burnett (1827), equally well in the same year. Mayo (1838), reviewing examples of slowness of the pulse and quoting Spens, included one such case; and Holberton (1841) added another. Stokes (1846) wrote the important paper that drew general attention to the subject: because of this; and because Huchard (1899) originally proposed the term Stokes-Adams disease, we strongly favour its retention in this order and excluding the use of the word " syndrome ", which would imply that all similar cases whatever the underlying pathology were to be included.

Shortly after Stokes's publication, the discovery was made of the slowing effect on the heart of vagal stimulation, and this governed the views on bradycardia until the end of the last century. Since 1900, with development of our knowledge of heart block, the newer conception placed bradycardia in general as due to an intrinsic myocardial lesion and seldom to a vagal effect. But from this division into neurogenic and myocardial causes another difficulty arises when we consider the definition of Stokes-Adams disease to-day. As our knowledge of the disease is infinitely greater, there is need to define it afresh. Shall it include all cases of cardiac syncope whether these result from vagal action or from ventricular asystole of myocardial origin? We think not, believing that heart block of some grade should be present at some time if the term Stokes-Adams attack is to retain a distinctive meaning. Our reasons are that the great majority of the clinical cases in question are due to myocardial disease with block and that their course, prognosis, and treatment are similar; whereas the reported cases of neurogenic origin (usually without block) are rare and of varied ætiology and prognosis, and may reasonably be classified as cardiac syncope.

Definition.—Stokes-Adams disease is a name applicable to patients with heart block who suffer from recurrent attacks of loss of consciousness due to ventricular standstill, ventricular tachycardia, ventricular fibrillation, or a combination of these.

During a Stokes-Adams attack from ventricular standstill the auricle continues to beat, whereas in other cardiac syncopes as a rule there is total cardiac standstill.

The term cardiac syncope may be reserved for attacks in patients without heart block due to total cardiac standstill from neurogenic or myocardial causes.

Cardiac syncope of neurogenic origin.—An ordinary faint in healthy people is most often of vaso-vagal origin with a fall of blood pressure combined with bradycardia (Cotton & Lewis, 1918), and we have recorded this event in a healthy man of 40, who happened to faint in the cardiographic chair (Fig. 1). In healthy people, too, vagal, carotid sinus, or ocular pressure (Fig. 2) may

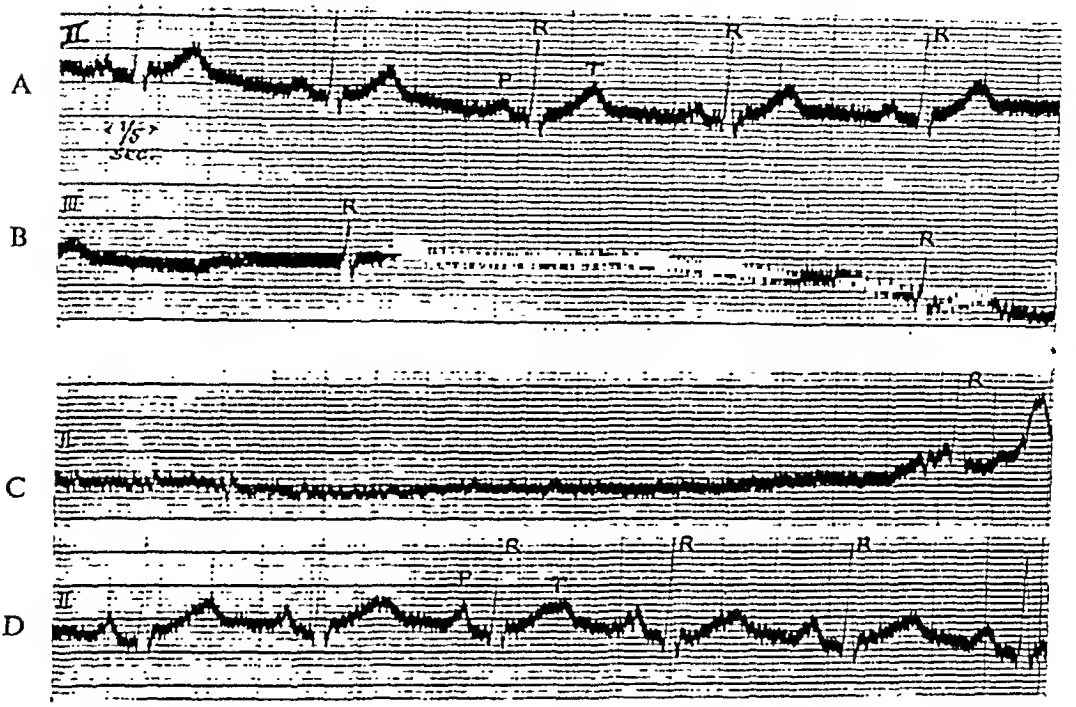

FIG. 1.—Syncope in a healthy man. (A) Before ; (B) During faintness; (C) Syncope; (D) Recovery.

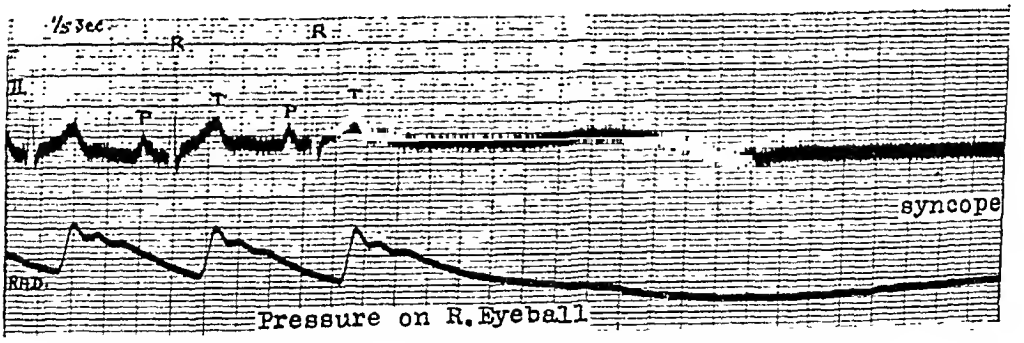

FIG. 2.—Induced syncope in a healthy boy. Pressure on right eyeball.

produce bradycardia and even ventricular standstill with syncope (Lewis, 1925). Transient A-V block may thus be induced (Weiss & Baker, 1933). There are rare but interesting cases of syncope from disease of or near the carotid sinus, or affecting the vagus in its course (Cassidy, 1928; Cassidy & Page, 1928; Gluch, 1932; Weiss & Ferris, 1934; Levy, 1939). A few of

them have been reported as Stokes-Adams attacks, but such cases are not included under our definition, though they are on the borderline, certainly when associated with transient and neurogenic A-V block (Weiss & Ferris, 1934).

Cardiac syncope of myocardial origin.—Paroxysmal ventricular tachycardia (Allan, 1926; Lukl, 1937; Grœdel & Kisch, 1939), the same as a complication of nodal bradycardia (Dressler, 1929) or from severe myocardial damage during a fatal infection (Schwartz & Jezer, 1934), may produce loss of consciousness and approximate to a Stokes-Adams attack. The episodic nature of the attacks, and the absence of heart block distinguish them from it.

In auricular flutter, syncope may be determined by the assumption of a 1: 1 rhythm at the high auricular rate. Fæssler (1939) has described the case of an infant in which nodal bradycardia without standstill produced syncopal attacks.

Incidence of and Varieties of Stokes-Adams Attacks

Only a proportion of patients with heart block get Stokes-Adams attacks. Of Cowan and Ritchie's (1935) 78 cases of complete heart block, one third gave a history of attacks. In Graybiel and White's (1936) series of 72 cases, there were 44. Figures for their incidence in partial or variable block are scarce, but Downie (1929) found Stokes-Adams attacks distinctly more common in partial block than in complete block. It seems likely that a block changing from partial to complete, and a rapidly developing block are periods most susceptible to Stokes-Adams attack, but it is a mistake to assume that with established complete heart block a patient becomes immune from attacks.

It is widely believed that ventricular standstill is the only common disturbance of mechanism which, supervening in heart block, determines the loss of consciousness; and this is implied in many text-book descriptions. But other disturbances of the cardiac mechanism may be responsible for the cerebral attack, and it was with the object of deciding the relative frequency and importance of the mechanisms of the actual Stokes-Adams attack that this investigation was made.

We have restricted our inquiry to cases in which an electrocardiogram was recorded during the unconsciousness of a Stokes-Adams attack. Of these we have 8 at our disposal, and we have collected and studied 56 reported cases. As a consequence we have been led to adopt the following classification :—

Group I.—Ventricular standstill alone.

28 reported cases; and our Cases 1, 2, 3, 4, 5. (Table I).

Group II.—Ventricular tachycardia followed by ventricular standstill.

(*a*) Low ventricular tachycardia (low V.T. in this paper means a rate below 160) followed by ventricular standstill; 3 reported cases and our Case 6. (Table II*a*.)

(*b*) High ventricular tachycardia (high V.T. means in this paper a rate between 200–500), usually also with ventricular fibrillation, followed by ventricular standstill; 13 reported cases and our Case 7. (Table II*b*.)

ABBREVIATIONS USED IN TABLES

A.	=	auricle	H.F.	=	heart failure
A.F.	=	auricular fibrillation	L.B.B.B.	=	left bundle branch block
A.P.	=	angina pectoris	N.R.	=	normal rhythm
B.B.B.	=	bundle branch block	R.B.B.B.	=	right bundle branch block
B.P.	=	blood pressure	Sl.	=	slight
C.H.B.	=	complete heart block	St. Ad.	=	Stokes-Adams attack
C.T.	=	coronary thrombosis	V.	=	ventricle
EC.	=	electrocardiogram	V.F.	=	ventricular fibrillation
Ex.s.	=	extrasystole (ventricular)	V.St.	=	ventricular standstill
H.B.	=	heart block	V.T.	=	ventricular tachycardia

TABLE I

GROUP I.—STOKES-ADAMS ATTACKS DUE TO VENTRICULAR STANDSTILL ALONE

Author	Age	Sex	Clinical features	EC. between attacks	EC. immed. before attack	EC. during attack	EC. immed. after attack	Unconsciousness (duration)	Outcome
Wilson and Robinson (1918)	48	F.	St. Ad. one day	(*a*) C.H.B.; V. 66, A. 110 (*b*) 4:1 and 2:1 H.B. (*c*) N.R. (110) P–R 0·32 sec.	C.H.B.; V. 90; A. 110	V. St., A. to 120	C.H.B. V. 90	(V.St. 7–11 sec.)	Improved
Hay (1921)	—	—	—	—	N.R. 50 to 64, P–R 0·26, B.B.B.	V.St., A. 66–88	—	(V.St. 5·5 sec.)	—
Wiltshire (1923)	64	M.	Slow reg. pulse	C.H.B.	—	V.St., A. rapid then slow; occas. flutter	—	1–1·5 min.	—
Wenckebach and Winterberg (1927) Case 1.	—	—	—	(*a*) N.R., B.B.B. (*b*) partial H.B. (2–5:1)	Normal P–R, then A.rapid; dropped beats	V.St., A. reaches 150	V.T. (140 in one attack)	(V.St. 18–23 sec.)	—

Wenckebach and Winterberg (1927) Case 2.	16	F.	—	(*a*) P–R+ (*b*) Partial H.B., B.B.B.	C.H.B.; V.39, A. 110; occas. 2: 1 H.B.	V.St.	—	(V.St. 11 sec.)	—
Wenckebach and Winterberg (1927) Case 3.	—	M.	St.Ad. weeks; produced on emotion, never on exertion	Variable H.B.	2: 1 then 3: 1 H.B.	V.St., A to 120	—	(V.St. 7·8 sec.)	Died during attack
Stechcr (1928)	65	M.	St.Ad. one week	C.H.B.; V. 20–30, A. 60–70	—	V.St., A. 58–76, ectopic P.	3: 1 H.B. P–R 0·36 sec.	10–20 sec. (V. St. 10 sec.)	Attacks ceased
Heimann (1929) Case 1.	60	M.	—	(*a*) C.H.B. (*b*) 2: 1, 3: 1 H.B. (*c*) P–R+; B.B.B.	—	V.St., A. 80 irreg.	—	34 sec.	—
Heimann (1929) Case 2.	—	—	—	—	—	V.St., occas. with A.F.	—	8 sec.	—
Yater and Willius (1929)	74	M.	St.Ad. 3 months. B.P. 240/105	(*a*) 3: 1, 2: 1 H.B. (V. 38; A. 75). (*b*) N.R. 75	C.H.B.; B.B.B. V, 55, irreg., A. 120	V.St., A. 130, then 50, then V.St., no P.	Basic compl. C.H.B.; V.10, A. 100	(V. St. 16–35 sec.)	Died during attack. Necropsy
Cheer and T'ang (1932)	66	M.	St.Ad. 10 months	N.R. 85	C.H.B.	V.St., A. 120	N.R.; P–R 0·18–0·20 sec.	(V.St., 3·6 sec.)	Attacks ceased
Condorelli (1932)	72	M.	—	(*a*) P–R+ (*b*) C.H.B. Partial B.B.B.	C.H.B. 20	V.St.	V.T.	18 sec.	—
Wood (1932)	48	M.	St.Ad. 9 months	C.H.B.; V. 20–30, B.B.B.	—	V.St. A. 75–86	—	2–3 min. (V. St., 7·5 sec.)	Attacks ceased
Géraudel and Others (1933)	78	F.	B.P. 210 70; uræmia	(*a*) 2: 1 H.B.; V. 30, A. 60; partial B.B.B. (*b*) 1: 1 H.B.; V. 60	H.B.; V. 63, A. 71	V.St., P. quickens	H.B. as preceding	15–40 sec.	Death during attack. Necropsy

TABLE I—*continued.*

Author	Age	Sex	Clinical features	EC. between attacks	EC. immed. before attack	EC. during attack	EC. immed. after attack	Unconsciousness (duration)	Outcome
Pardee (1933)	—	—	—	—	C.H.B.; V. 54, A. 96, R.B.B.B. B. then normal QRS	V.St.	—	(V.St. 15 sec.)	—
Sachs and Traynor (1934)	43	M.	St.Ad. months. Normal heart	N.R. 80	—	V.St. A. 110	C.H.B.; V. irreg., A. 90; R.B.B.B. then N.R.	1 min. (V.St. 5 sec.)	Attacks ceased
Gilchrist (1934)	61	F.	St.Ad. one year	(*a*) 2: 1 H.B. P–R 0·18 sec. (*b*) C.H.B. V. 28, A. 70	2: 1 H.B. P–R 0·19 sec.	V.St.	3: 1 H.B.	(V.St. 10 sec.)	Attacks ceased
Laufer (1934)	68	M.	St.Ad. preceded by angina	(*a*) P–R 0·26–0·32 sec. Partial B.B.B. (*b*) 2: 1, 3: 1 H.B.; C.T. (post.)	Sinus tachycardia. P–R 0·36, dropped beats	V.St. A. 92–142	2: 1, 3: 1 H.B.	(V.St. 11 sec.)	Attacks ceased
Cowan and Ritchie (1935)	49	F.	—	—	—	V.St. (A. 120)	—	(V.St. 11 sec.)	—
Clerc and Levy (1936). Case 1	67	M.	St.Ad.months. H.F.	C.H.B. V. 38; A. 95	—	V.St. occas. P; then V.T.	V.T.100–48 —27	(V.St. 30 sec.)	Died after 4 years (cerebral thromb.)
Schwartz (1936,b)	53	M.	St.Ad. one day, with C.T.	(*a*) C.H.B. (*b*) N.R.	—	V.St. A. 110	C.H.B.; then N.R.	(V.St. 9·5 sec.)	Attacks ceased Necropsy
Hermann and others (1937)	65	M.	St.Ad. 14 years. P. 80, reg.	(*a*) N.R. 75; partial B.B.B. (*b*) C.H.B. only day before death.	N.R. A. 100; dropped beats	V.St. A. 110–50 Ectopic P.	Nodal (A–V) rhythm, then N.R. also V.T.	(V.St. 45–150 sec.)	Died in observed attack Necropsy

Norris and Landis (1938). Case 1	—	—	—	—	—	V.St., variable P.	—	(V.St. 4 sec.)	—
Cossio (1939)	—	—	—	—	C.H.B.; V. 34, A. 105	V.St., A. to 120	—	(V.St. 8·5 sec.).	—
Laplace (1939)	29	M.	—	C.H.B.; V. 50, A. 135	C.H.B.	V.St., P. slow then absent	—	—	Died in observed attack
Sigler (1939, A)	57	M.	A.P.	N.R.; R.B.B.B.	2: 1 H.B. then C.H.B.	V.St., P. 100–116	2: 1 H.B., also N.R.	30–60 sec.	Attacks ceased
Scherf and Boyd (1940)	—	—	H.B. after C.T.	—	C.H.B.	V.St.	C.H.B.	(V.St. 90 sec.)	—
Teran (1941)	51	M.	St.Ad. 4 months. B.P. 190/100;	(*a*) C.H.B.; V. 15 A. 100 (*b*) 2: 1 H.B. R.B.B.B. (*c*) N.R. 66	—	V.St., A. 60–95. Ectopic P.	N.R. 66; P–R 0·22; R.B.B.B.	(V.St. 8–10 sec.)	—

The above Table 1 comprises 28 reported cases in Group I, to which our Cases 1, 2, 3, 4, 5 also belong.

TABLE II

GROUP II.—VENTRICULAR TACHYCARDIA FOLLOWED BY VENTRICULAR STANDSTILL

(*a*) Low ventricular tachycardia (below 160) followed by ventricular standstill.

Author	Age	Sex	Clinical features	EC. between attacks	EC. immed. before attack	EC. during attack	EC. immed. after attack	Unconsciousness (duration)	Outcome
Gager and Pardee (1925)	59	M.	St.Ad. 2 weeks	(*a*) C.H.B.; V. 27–15; A. 92. (*b*) 2: 1 H.B. (*c*) N.R. 60	V.T. (V. 60; A. 100) then V.St.	V.St. A. 100	—	0·5–1 min. (V.St. 6–20 sec.)	Died after 6 months during attack
Herapath (1926)	63	M.	B.P. 210	(*a*) C.H.B.; V. 35; Ex.s. (*b*) C.H.B.; QRS. of the ex.s. type (*c*) 2: 1 H.B. L.B.B.B.	V.T. QRS of ex.s. type, rate 62	V.St. A. rate +	—	(V.T. 40 sec. V.St. 12–15 sec.)	No further attacks
Coelho (1932)	—	—	—	—	V.T.	V.St.	—	—	—

(*b*) High ventricular tachycardia (200–500), usually also with ventricular fibrillation, followed by ventricular standstill.

Kerr and Bender (1922)	68	M.	H.F. 4 years	C.H.B.; A.F.; R.B.B.B. V. 30–36	V.T. 180–220	V.F. then V.St.	—	1–2 min.	Recovery from attack.
Hœsslin (1925)	31	F.	Slow pulse	C.H.B.; V. 32–34; Ex.s.	—	V.F. then V.St. P. modified during V.St.	V.T. 132–134; of each group QRS has different shape	—	—
Levine and Matton (1926)	52	F.	—	(*a*) C.H.B.; R.B.B.B. (*b*) 3 months later, inversion of T_2 and T_3	Variable Ex.s.	V.T. (? V.F.) 240; V.St. A. 45	V.T. 140; after 7 min. 70	V.F. 200 sec. V.St. 80 sec.	Attack ceased.
Freundlich (1932)	69	F.	B.P. 250/70; St.Ad. one day, preceded by angina	C.H.B.; V. 48; Ex.s.	Multiple, variable Ex.s. V.T. at increasing rate	Irreg. V.T. (? V.F.) 280; V.St.	T inverted in all leads; coronary R–T	5 min. (V.F. 80 sec.; V.St. 7·5 sec.)	Attacks ceased

Lian and Deparis (1934)	52	F.	St.Ad. 2 years; B.P. 220/90	C.H.B.; V. 35, A. 78; partial B.B.B.	—	V.F. 300; V.T. 200; then basic complexes. Once V.St. A. to 120	C.H.B.	1–1·5 min. (V.St. 12 sec.)	Died during attack
Clerc and Lévy (1936) Case 2	75	F.	St.Ad. 9 years	(*a*) C.H.B.; V. 32: (*b*) N.R., P–R Sl.+, R.B.B.B	—	V.F. (280) then V.St.	V.T. 200 for 7 min., then C.H.B.	6 min. (V.St., 60 sec.)	Alive after 10 months: few attacks
Jezer and Others (1936) Case 1	68	M.	St.Ad. 5 months; H.F.	C.H.B.; 30	V.T. 60–120	V.St., A. up to 165, then V.T.	—	Hours; (V.St. 90–180 sec.)	Died after few hours of V.St. and V.T.
Jezer and Others (1936) Case 2	39	M.	St.Ad. 18 months; B.P. 175/85	C.H.B.; A. 70, V. 25.	V.T. 120 then C.H.B. 25, then V.St.	V.St.	V.T. 75 to 120, then V.St. again	(V.St. 30–60 sec.)	Died in observed attack
Spühler (1936)	51	F.	St.Ad. 4 months; A.P. 16 months	(*a*) C.H.B.; B.B.B., (*b*) 2: 1 H.B.; B.B.B.	C.H.B., B.B.B., multiform Ex.s.; A. 125	V.T. (270). V.St., A. 40, irreg.	V.T. (130); then C.H.B.; V55, A. 170, with normal QRS	2–8 min. (V.T. 115 sec.; V.St. 8 sec.)	—
Froment and Gonin (1938, A)	60	M.	St.Ad. 10 years; H.F.	C.H.B.; V. 13, A. 35; L.B.B.B.	V.T. 60.	V.St. P. later disappears. Occasional V.T. 300	V.T. 40–48–28, then V.St.: 4 hours alternate V.St. and V.T.	(V.St. 30 sec.)	Died in V.F.
Gertz and Others (1938)	59	F.	St.Ad. years	(*a*) N.R. (*b*) 2: 1 H.B.	C.H.B. Ex.s.	V.T. 250 and V.F.; V.St.	C.H.B.	(V.F. 83 sec. V.St. 50 sec.)	Died in observed attack
Norris and Landis (1938). Case 2	—	—	—	C.H.B.	—	V.T. 160, V.St. (A. 100); V.F. 150–200	—	20 min.	Died after two days
Soulié (1938)	68	F.	St.Ad. 2 years, following C.T.	2: 1 H.B.; L.B.B.B.	2: 1 H.B.; C.H.B.	V.St. absent P. V.T. for 600–800 sec. then again V.St.	Multiform Ex.s. C.H.B. with aur. flutter	(V.St. 70–130 sec.)	Died in observed attack

The above Table II, comprises (*a*) 3 reported cases in Group II (*a*), to which our own Case 6 also belongs; and (*b*) 13 reported cases in Group II (*b*), to which our own Case 7 also belongs.

TABLE III

GROUP III.—HIGH VENTRICULAR TACHYCARDIA, OR VENTRICULAR FIBRILLATION, OR BOTH. NO VENTRICULAR STANDSTILL

Author	Age	Sex	Clinical features	EC. between attacks	EC. immed. before attack	EC. during attack	EC. immed. after attaek	Uneonseious-ness (duration)	Outeome
Gaillard (1923)	62	M.	St.Ad.; ehronic nephr., B.P.+	C.H.B. with A.F. (V. 40)	—	V.T. (200)	V.T. at low rate	—	Died after 1 month
Gallavardin and Bérard (1924)	55	F.	St.Ad. 4 years	C.H.B.; V. 35–42, A. 85	—	V.F. (336)	C.H.B.	2·5 min.	—
Heimann (1929) Case 3	46	F.	H.F., B.P.+	Partial H.B.	—	V.F. (? V.T.) 200	—	10 sec.	Died during attaek
Gallavardin and Froment (1931)	39	M.	Subaeute baet. endoearditis; St.Ad. 5 days before death	C.H.B. (40)	N.R. then 3: 1, 2: 1 H.B., partial B.B.B., then V.T.	V.T.	—	—	Died after 5 days
Schwartz and Jezer (1932)	65	F.	St.A. 5 months; H.F.	C.H.B.; V. 28, A. 66; QRS. normal or B.B.B.	Multiple Ex.s.	V.T. and V.F., rate 250–500	Low V.T. to 90, then basic rhythm	10–180 sec.	—
Bizzozero (1934)	60	F.	Diabetes; St.Ad. 1 month. H.F.	C.H.B.; V. 40, A. 110; partial B.B.B.	—	V.F. (and V.T.) 230	—	—	—
Sehwartz and Hauswirth (1934)	56	F.	St.Ad. 6 months; B.P. 230/120	(*a*) Sinus taehyc., normal P–R, R.B.B.B. (*b*) 3: 2 H.B. (*c*) C.H.B.	Multiple ex.s.	V.T. and V.F. 250–300	—	Several min.	Died after 1 year with syn-eope
Kahall (1935)	68	M.	St.Ad. 3 days; B.P. 200/100; P. 34–40	—	C.H.B. multiple ex.s.	V.T.; V.F.; or V.T. only	C.H.B., slow ventr. rate	20–120 sec.	Died after 6 weeks in attaek.

Sigler (1938)	58	M.	St.Ad. months; A.P.	Normal P–R, 3: 2 H.B.	As between attacks; runs of Ex.s.	V.T. 220–250; V.F. 370–195	C.H.B.; after 300 sec. V.T. 130	1–2 min.	Attacks ceased
Turrey and Leamann (1929)	—	—	—	C.H.B.	Multiform Ex.s. in runs	V.T. (240), V.F., V.T. with occas. V.St. and absent P.	V.T., C.H.B., Ex.s.	(V.F. 42 sec.)	—
Sigler (1939, B)	66	F.	Diabetes, C.T.; 6 months later St.Ad.	C.H.B.	—	V.T. (250), V.F. (370), V.T.	—	5 hours intermittently	—
Fishberg (1940)	—	—	—	C.H.B.	C.H.B., multiform Ex.s.	V.T. 200–300, then V.F.	—	(V.F. 19 sec.)	—

The above Table III comprises 12 reported cases in Group III, to which our own Case 8 also belongs.

Group III.—High ventricular tachycardia, or ventricular fibrillation, or both, without ventricular standstill.

12 reported cases and our Case 8. (Table III).

Group IV.—Extreme bradycardia with complete heart block.

No table is given for this group because it is small and less important. Many early reports tell of extreme slowness of the pulse as the sufficient cause of the faint, yet electrocardiograms of such cases are hard to find. That of Gilchrist (1934) is an example, yet that was the result of stoppage of ephedrine therapy. The case of Dubbs (1938) is a clear example though it is surprising that the ventricular rate was not lower than 20.

Authors' Case Reports

Case 1, *male*, *aged* 54.

History.—Three years ago and six months ago he lost consciousness. Recently the attacks became frequent and he was admitted to hospital, where he died four days later during an attack. There was no history of rheumatic fever, chorea, or diphtheria.

Examination.—The pulse was regular and 30 a minute, but next day it fell to 16, persisting at this rate between the attacks until he died. There was no clinical evidence of cardiac enlargement and there were no murmurs. Signs of heart failure, including distension of the liver and œdema of the ankles, appeared on the third day in hospital. The blood pressure (B.P.) was 120/65. The Wassermann reaction (W.R.) was negative.

Course.—He was seen in several Stokes-Adams attacks which occurred about every hour during the last two days of life. A momentary feeling of faintness preceded unconsciousness, then the respiratory movements became exaggerated and profuse sweating accompanied a great pallor. The pupils dilated ; the upper limbs twitched. With the onset of unconsciousness the pulse stopped and the ventricles ceased to beat (auscultation)—for 25 seconds in one attack. When the pulse returned, it was regular at 16 and consciousness was quickly regained. Occasionally the heart sounds were absent for periods over 10 seconds without complete loss of consciousness. Vomiting commonly followed the attacks, but there was no incontinence of urine.

On one occasion, adrenalin (3 minims of 1 in 1000 solution intravenously) quickened the pulse to 72 within one minute, but two minutes later it was 32, and 30 minutes later, 16. On another occasion, two successive injections (5 minims subcutaneously) had no effect on the pulse rate.

Electrocardiographic features

(*a*) *Between* the attacks there was complete heart block (C.H.B.) with a regular ventricular rate of 33 to 25 and an auricular rate of 100. The ventricular complexes were of right bundle branch block (B.B.B.) type (QRS, 0·16 sec.) with deep inversion of T_2 and T_3.

(*b*) *During* the attack (Fig. 3) ventricular standstill was recorded for 3·8 seconds with an increased auricular rate of 150.

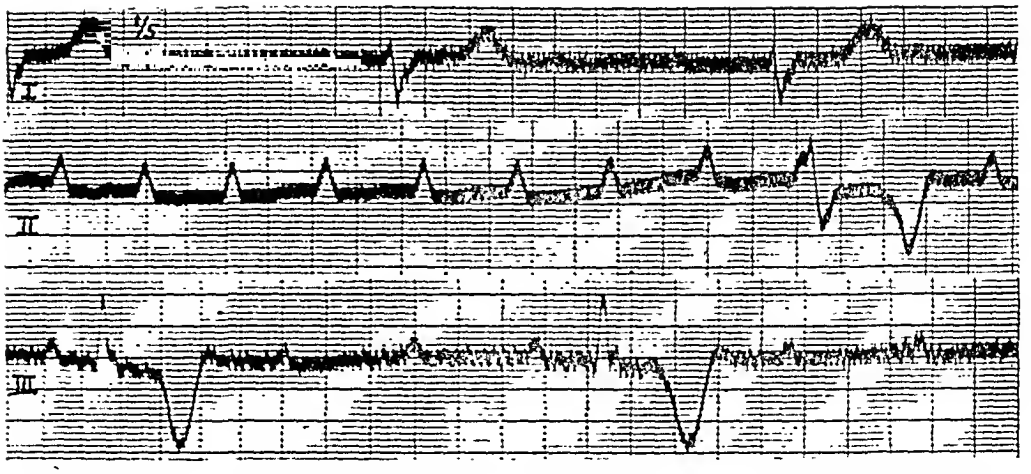

FIG. 3.—Case 1. Stokes-Adams attack. Ventricular standstill. Complete heart block.

Case 2, *male*, *aged* 76.

History.—Some heart affection had been recognized for years. Fainting attacks, some with convulsions, occurred for the first time on the day before admission to hospital.

Examination.—The pulse was regular, owing partly to extrasystoles; the rate varied between 30 and 72. The heart sounds were normal, and on X-ray examination the heart was of normal size and the aorta was unfolded. There was no evidence of heart failure, nor of any other than cardiovascular disease. B.P., 180/80.

Course.—In hospital the attacks were at first frequent, sometimes 3–4 a day and each lasting about 30 seconds. He lost consciousness suddenly and his breathing became stertorous; no pulse could be felt and no heart sounds could be heard. He had oral treatment with ephedrine and thyroid, and injection treatment with adrenalin. Gradually he improved and there were no attacks during the last weeks in hospital. He became quite well, and when last seen, four years later, he was still free from attacks.

Electrocardiographic features

(*a*) *Between* the attacks there was at first partial or complete heart block with a ventricular rate of 50–75, apart from multiform extrasystoles. The basic complexes were of supraventricular type (QRS, 0·07 sec.). Fig. 4 was taken at this period. Three days after admission, sinus rhythm returned with a P–R interval of 0·3 sec. The successive records taken in hospital and a fortnight after his discharge were similar. Five months after his discharge, partial heart block was recorded with an irregular ventricular rate of 50–63 and a regular auricular rate of 80. Sinus rhythm with prolonged P–R interval returned one month later, and the last record taken two and a half years later was similar, with only a widened ventricular complex (QRS, 0·12 sec.) of partial bundle branch block appearance.

(*b*) *During* the attack (Fig. 4) there was ventricular standstill recorded during 4 seconds, during which the auricular rate increased from 66 to 86. At the end of the standstill there was partial heart block.

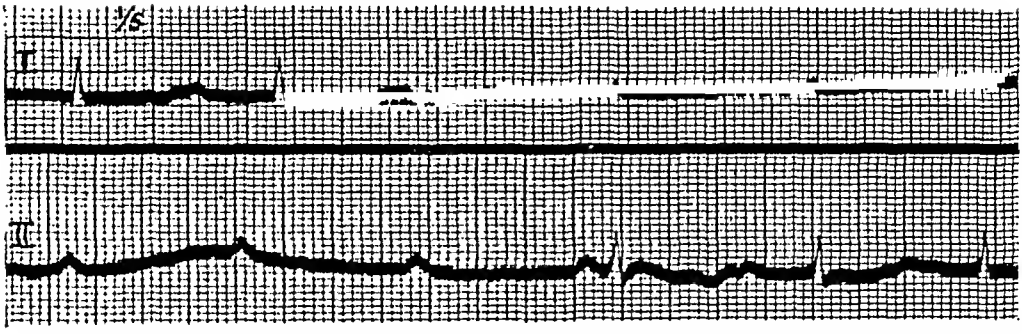

FIG. 4.—Case 2. Stokes-Adams attack. Ventricular standstill. Partial heart block.

Case 3, *male, aged* 68.

History.—For years had been treated for high blood pressure. For one year, recurrent attacks of anginal pain. A few days before examination had attacks of giddiness, sometimes followed by loss of consciousness. The day before examination the syncopal attacks became very frequent.

Examination.—The blood pressure was raised; there were no signs of failure. While being examined, he fainted repeatedly. The colour of the face alternated between pallor and flushing, the breathing became irregular and sometimes ceased for seconds. The slow, regular pulse of about 50 stopped suddenly for some seconds, the heart sounds were inaudible and the patient fell back unconscious. Even when the pulse returned, he was mentally clouded the whole day. He became worse, and died a few days later.

Electrocardiographic features.

(*a*) *Between* the attacks there was complete heart block with a ventricular rate of 57, and an auricular rate of 80, both regular. The basic ventricular complexes were supra-ventricular (QRS, 0·08 sec.) with an inverted T_1.

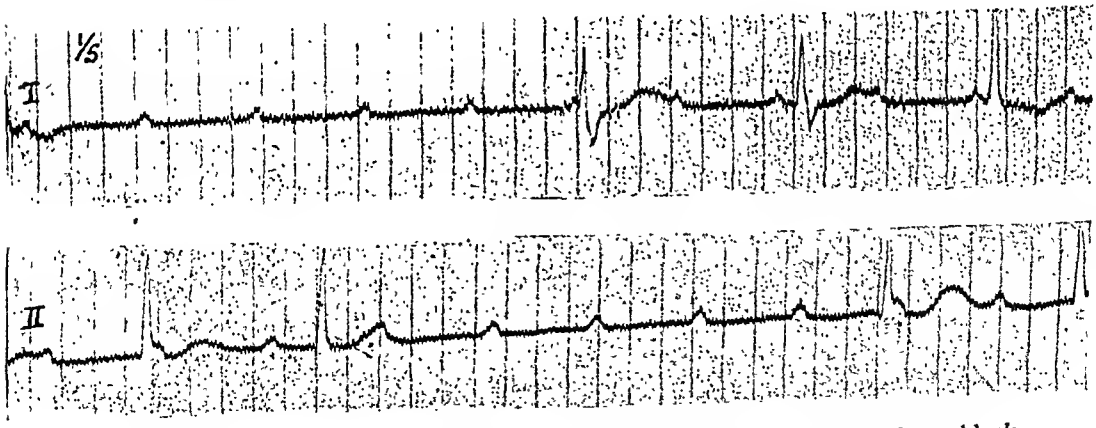

FIG. 5.—Case 3. Stokes-Adams attack. Ventricular standstill. Complete heart block.

(*b*) *During* the attacks (Fig. 5) there was ventricular standstill recorded during 4 and 3·6 seconds respectively. The first ended with an ectopic ventricular complex followed after 1·4 seconds by a similar one. The second attack ended with two basic ventricular complexes at a rate of 46 a minute, but from the third complex onwards the rate was again 57. At the end of the first and longer standstill the auricular rate slightly increased to 92, and the original rate

of 80 was regained only 5 seconds after the appearance of the basic ventricular complex. The second and shorter ventricular standstill left the original auricular rate unaltered.

Case 4, *male, aged* 43.

History. The first attack of unconsciousness happened 14 months ago. No attacks for 4 months, then they became frequent. He was admitted to hospital for observation as epilepsy was suspected. There was no history of acute rheumatism, chorea, or diphtheria.

Examination.—The pulse was regular, 70 a minute. The heart was not enlarged and there were no murmurs; other systems showed no abnormal signs. B.P., 140/80; W.R., negative. During a stay of 38 days in hospital no fewer than 590 attacks were noted. In many he remained fully conscious and complained of a burning sensation over the stomach which spread upwards to the chest, to the neck and face, and sometimes along the arms to the fingers and down the legs to the toes. During such paroxysms he expected to faint, but only turned pale and breathed rapidly. In some of them the pulse stopped and the ventricles ceased beating (auscultation) for periods of 5 seconds or more, jugular pulsation (auricular contraction) continuing. This ventricular standstill was often recorded by electrocardiograph. In almost as many attacks consciousness was lost, and then ventricular standstill lasted 10 to 20 seconds, the patient becoming unconscious towards the middle of the period, the breathing stertorous, and the face muscles twitching.

Course.—The attacks gradually became less frequent, and a month after discharge from hospital they ceased. Later he reported none for three years, and was able to do light work.

Electrocardiographic features. In all, 15 electrocardiograms were taken and they showed that the block was paroxysmal.

(*a*) *Between* the attacks there was most often sinus rhythm at a rate of 85, with a normal P–R interval and normal ventricular complexes (Fig. 6A). On

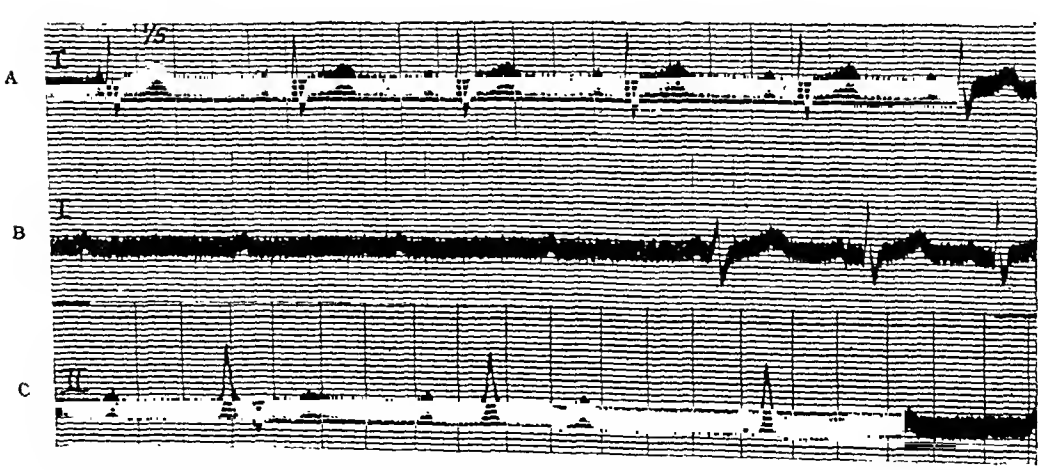

FIG. 6.—Case 4. Stokes-Adams attack. Paroxysmal heart block. (A) Sinus rhythm, normal P–R. (B) Ventricular standstill ending with sinus rhythm. (C) Complete heart block. (B) was taken immediately after (A); (C) on another day.

other occasions complete heart block was recorded with a ventricular rate of 55 and an auricular rate of 90 (Fig. 6C).

(*b*) *During* the attack there was ventricular standstill recorded during 3 seconds. It began abruptly during sinus rhythm with a delayed auricular beat not followed by the ventricular complex (not shown), and ended with an ectopic beat 0·10 second after P, when the sinus rhythm continued at the usual rate of 85 (Fig. 6B). During the standstill the auricular rate increased from 66 to 75.

Case 5, *male, aged* 70.

History.—No complaints until two and a half years before, when he suddenly fell down unconscious in the street. Occasional short faints followed at varying intervals, and for one week as frequently as every day. The day before admission, the attack was more severe; he became extremely pale, and unconscious, and seemed about to die. For months he had noticed dyspnœa and palpitation.

Examination.—He was pale, and every few minutes fainted. The pulse was irregular, about 24 a minute; there was slight enlargement of the left ventricle, and moderate uniform widening of the aortic shadow on radioscopy. The heart sounds were normal; there was no evidence of failure. B.P., 190/75; W.R., negative. The urine contained a trace of albumin.

Course.—Adrenalin (5 minims subcutaneously) did not increase the ventricular rate and did not prevent the recurrence of attacks. During the following 5 months he fainted about once a week, except that on one particular day he had twelve faints. The longest period of freedom was ten days.

Electrocardiographic features.—Polygrams showed complete heart block with frequent pauses of the radial pulse, the longest one recorded being of 8 seconds duration.

(*a*) *Between* attacks, the electrocardiogram showed complete heart block with a regular auricle at 86, and a regular ventricle at 33. The ventricular complexes were of small voltage and of left bundle branch block type (Fig. 7).

(*b*) *During* the attack (Fig. 7), the basic ventricular complex of left bundle

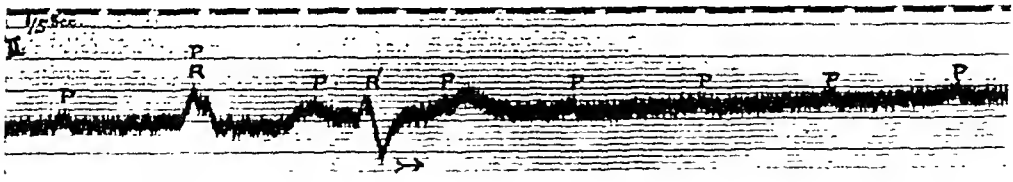

FIG. 7.—Case 5. Stokes-Adams attack. Ventricular standstill. Complete heart block.

branch block type was followed at a distance of 0·7 sec. by a ventricular extrasystole. Then came ventricular standstill, recorded for 2·6 seconds during which the auricular rate was 110. With the reappearance of ventricular action the auricular rate slightly decreased to 100. Ectopic ventricular complexes recurred at irregular intervals.

At the end of another attack (not shown), ventricular extrasystoles were followed after 2 seconds by the returning basic complex. The ventricular rhythm

later increased from 35 to 46 and then changed into a regular ventricular tachycardia at a rate of 60 with widened ventricular complexes of another shape.

Case 6, *male*, *aged* 40.

History.—Nine years dyspnœa, more severe for two years, appearing even on slight effort and compelling him to relinquish heavy work. Seven years, momentary faints (loss of consciousness) about once a month, ascribed to heavy meals or to effort. Ten months ago he had the first severe syncope; its duration was unknown, but there was twitching of face and hands, with incontinence of fæces during the attack, and vomiting after it. Since then he has had up to 100 similar attacks a day, though sometimes he was free for as long as 9 days.

Examination.—The pulse was regular, 28 a minute, and the rate could not be increased by exercise. The apex-beat was forcible but not displaced, and the cardiac dullness was normal. The heart sounds were distant and a faint systolic murmur was heard at the mitral area. The liver was palpable, but there were no other signs suggesting failure. B.P., 125/60 ; W.R., negative.

Course.—While in hospital few days passed without attacks, which were of two different kinds. Some were accompanied by disappearance of the pulse, loss of consciousness, clonic contractions, and incontinence; and they lasted 1–2 minutes. The others, during which he did not lose consciousness, started with a feeling of epigastric oppression, followed by " thumps of the heart ", then by a feeling of pins and needles in the neck which extended over the head. Both types of attack might often recur indifferently over a period of several hours. Adrenalin (5 minims subcutaneously) and barium chloride (0·5 grain, t.i.d.) did not influence the length of the attacks, nor prevent their recurrence. Attacks proved more frequent during a trial course of digitalis (tinct. digitalis. 10 minims, t.i.d.) for seven days. During five months of observation little change was noted and no signs of failure developed. He died in hospital after a succession of attacks in which he complained of epigastric tightness and flatulence. Necropsy was refused.

Electrocardiographic features

(*a*) *Between* the attacks there was always complete heart block with a regular or irregular ventricle at a rate of 20–30. The auricle was fairly regular at 66–86. The basic ventricular complexes were of right bundle branch block type (Fig. 8A). Ectopic ventricular complexes were frequent and varied in shape; they appeared both as extrasystoles following the basic complex, and as regular sequences of a slow ventricular " tachycardia " at 55–75.

(*b*) *During* the attacks several standstills of the ventricle were recorded, the longest lasting 6·8 sec. in which the auricular rate increased from 75 to 100 (Fig. 8B). They were always preceded by a low ventricular tachycardia. Periods with extrasystoles sometimes preceded the ventricular tachycardia.

Case 7, *female*, *aged* 62.

History.—Hypertension was discovered two years before when the patient was in hospital for pulmonary infarction following phlebitis. There was no history of rheumatic fever, chorea, or diphtheria. During the six weeks preceding her present admission she had two Stokes-Adams attacks.

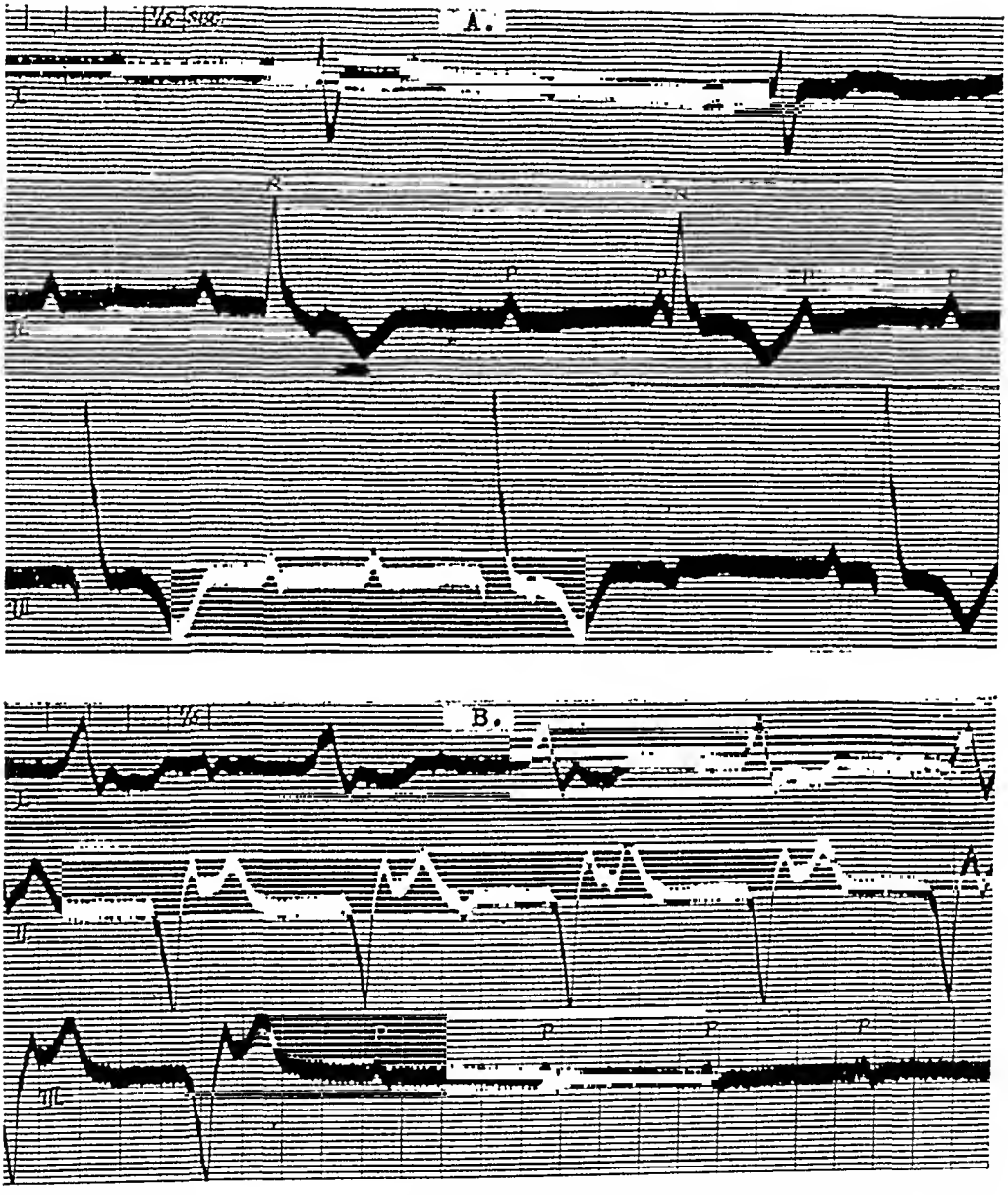

FIG. 8.—Case 6. Stokes-Adams attack. (A) Complete heart block, right bundle branch block. (B) Low ventricular tachycardia preceding ventricular standstill.

Examination.—She looked well and was rather stout. There were no abnormal signs except in the cardiovascular system. As a rule the pulse was regular and infrequent, 38. On radioscopy, the left ventricle was seen to be moderately enlarged. A systolic murmur was heard in both mitral and aortic areas. There was no evidence of heart failure. B.P., 205/110; W.R., negative. Many Stokes-Adams attacks were observed in hospital. On some days there were as many as five, but there might be no attacks for a week or longer.

Clinical features of the attacks.—Often one followed soon after a meal. The patient would complain of feeling suddenly ill and might call for a bed-pan.

Sometimes she would cry out that an attack was coming on. She then became unconscious, the breathing and the pulse stopped, and the heart ceased beating (auscultation). The cyanosed face twitched, and there were spasmodic movements of the arms and legs. The eyes turned up and the pupils dilated widely. The pulse returned after one to two minutes, when it was rapid (about 150 a minute) and usually regular, but later it would fall to about 38 a minute. The breathing, returning soon after the pulse, was stertorous and accompanied by a heaving movement of the chest. Cyanosis gradually disappeared and was usually replaced by slight pallor. After 5 to 15 minutes with returning consciousness she perspired, was exhausted and confused, uttering loud and wild shouts. Incontinence of urine often occurred during an attack.

Electrocardiographic features

(*a*) *Between* the attacks the electrocardiogram changed frequently from complete heart block to 2 : 1 or 3 : 1 heart block when, apart from the pauses, the P–R interval was normal. The ventricular complexes varied from left to right bundle branch block. The ventricular rate was often irregular owing to multiform ventricular extrasystoles. When regular, it varied between 32 and 40 and the auricular rate between 80 and 92.

(*b*) *During* the attack, Fig. 9 was recorded, and the sequence of events is portrayed in Fig. 10 (Chart). Immediately before the attack, the pulse was regular (38 a minute). While the camera was being loaded she lost consciousness suddenly and the breathing ceased. The pulse stopped, but after 30 seconds it returned and the electrocardiogram (Fig. 9A & B) first showed rapid ventricular tachycardia (270 a minute), and the irregular ventricular deflections of *ventricular fibrillation*. This phase lasted 30 seconds when the pulse again disappeared and Fig. 9C & D showed *cardiac standstill* for one minute, and rudimentary P waves 20·8 and 24 seconds after its onset. A subcutaneous injection of 10 minims of 1 in 1000 solution of adrenalin hydrochloride was given at the beginning of the standstill period. The pulse when it returned was regular and infrequent, and the Fig. 9E showed *complete heart block* with an auricular rate of 95 and a ventricular rate of 42. This phase lasted 12 seconds, and then the pulse rose to 135 a minute at the onset of tachycardia with changing ventricular complexes (Fig. 9F) lasting 5 minutes, the auricular rate increasing from 90 to 150 meanwhile. The breathing returned but became slow with long inspiratory and short expiratory phases. At this stage, although still unconscious and not responding to external stimuli, the patient began to utter wild and loud shouts. Fig. 9G showed complete heart block, the ventricular rate was 37 and the auricular rate was as rapid as 150 a minute. The second paroxysm of ventricular tachycardia shown on Fig. 10 (Chart) is not published as it was similar to Fig. 9F. After two minutes, during which the patient ceased to shout and recovered consciousness, the heart rhythm returned as complete heart block at 38. Altogether the patient had been unconscious for nine and a half minutes. We consider it unlikely that adrenalin had any effect upon the sequence of events just described.

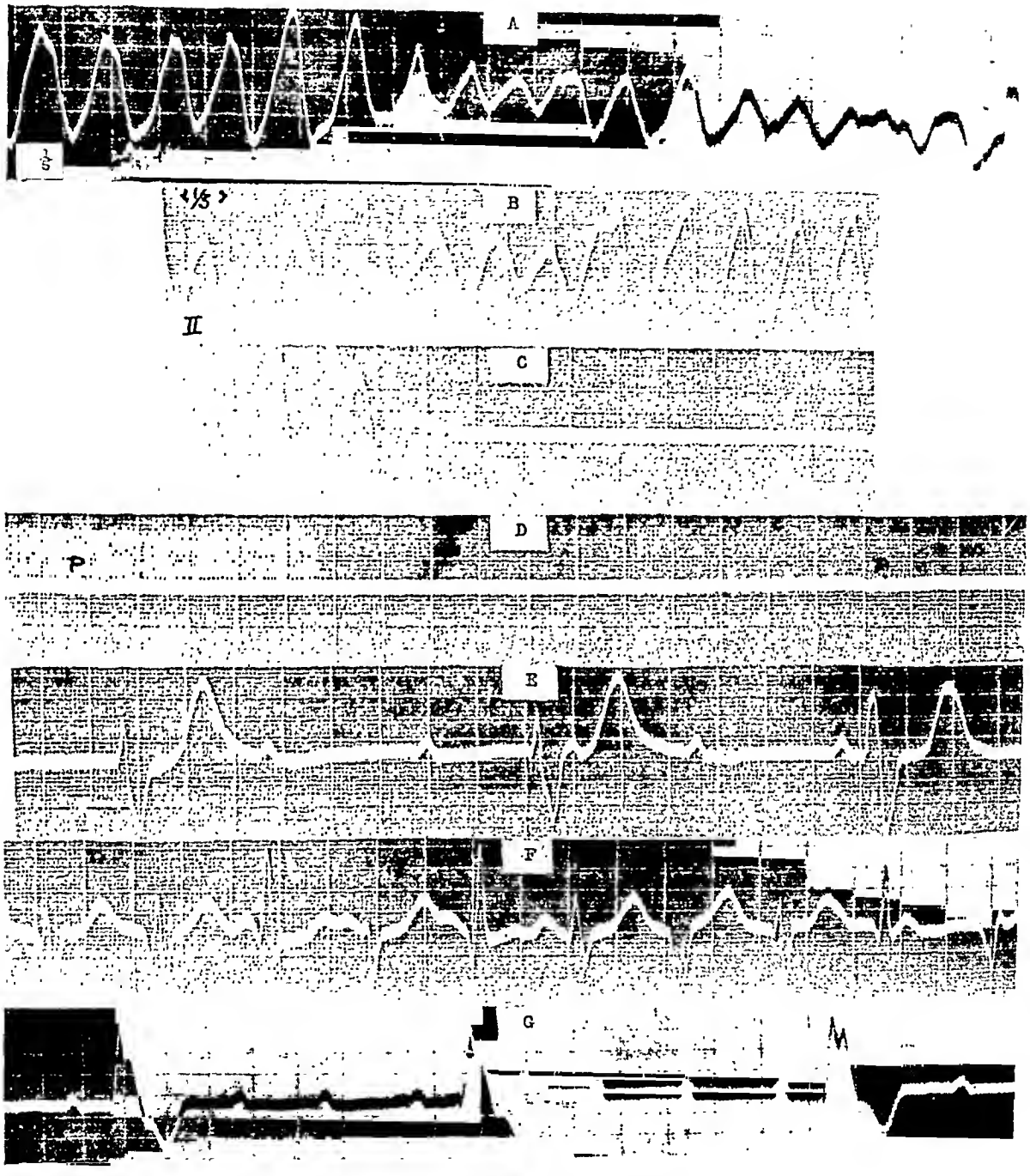

FIG. 9.—Case 7. Stokes-Adams attack. (A) and (B) High ventricular tachycardia and ventricular fibrillation. (C) End of ventricular tachycardia and onset of complete cardiac standstill. (D) Cardiac standstill with two ectopic P waves. (E) Complete heart block, right bundle branch block. (F) Tachycardia with changing ventricular complexes. (G) Complete heart block, left bundle branch block (basic complexes).
All records are lead II.

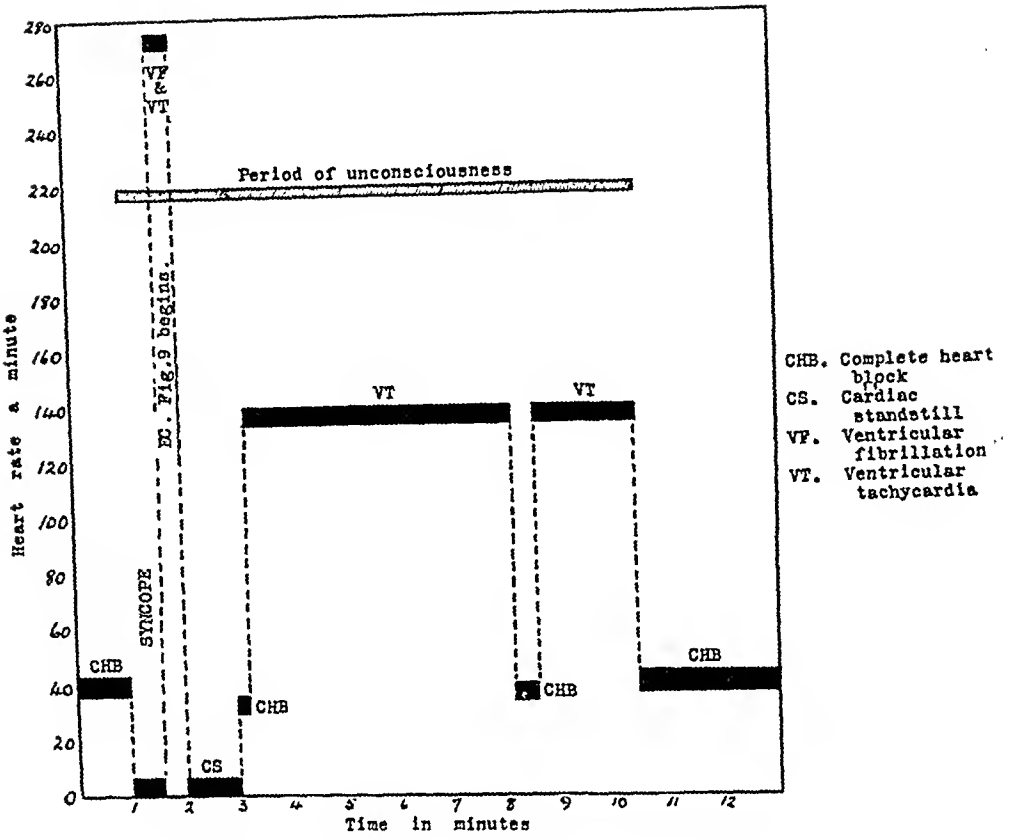

FIG. 10.—Chart of Stokes-Adams attack recorded in Fig. 9 (Case 7).

Case 8, *male, aged* 65.

History.—For seven months angina pectoris, and also dyspnœa on exertion. One week dizzy attacks while sitting. On day of admission he had a bout of dizziness, and later fell unconscious; sent to hospital.

Examination.—Pulse 40, irregular ; no murmurs. B.P. 240/90 ; W.R., negative. Next day an attack was observed; he felt faint, became pulseless, his face pale, then cyanosed and unconscious, then convulsions for two minutes. Respiration ceased, then returned ; he was unconscious from time to time and there were two further convulsions during the next hour. He died one and a half hours after the onset of the attack, during which numerous electrocardiograms were taken.

Necropsy showed a moderate degree of coronary sclerosis with calcification, more of the left than of the right coronary artery. No evidence of myocardial infarction could be found, although there was slight patchy fibrosis.

Electrocardiographic features (Fig. 11)

(*a*) *Between* the attacks there was complete heart block, with an irregular basic ventricular rhythm at 25–32. The auricular rhythm was regular, rate 100. Nearly all the basic complexes were followed at an interval of 0·52 sec. by a standard form of extrasystole with the main deflection downward. This was often followed by one or more different extrasystoles, and then the succeeding basic complex was of course delayed; hence the irregularity of the basic ventricular rhythm.

(*b*) *During* the attack, ventricular tachycardia lasted 6 seconds, and comprised in order : 6 downwards complexes (rate 200 approx.), 2 diphasic complexes, 6 upright complexes (rate 200–210), and 4 downward complexes (rate 200–120) approximating in form to the standard extrasystole. The pause after the tachycardia was no longer than the usual pause after an extrasystole, being about 1·2 seconds. This was confirmed by a short record of the end of another

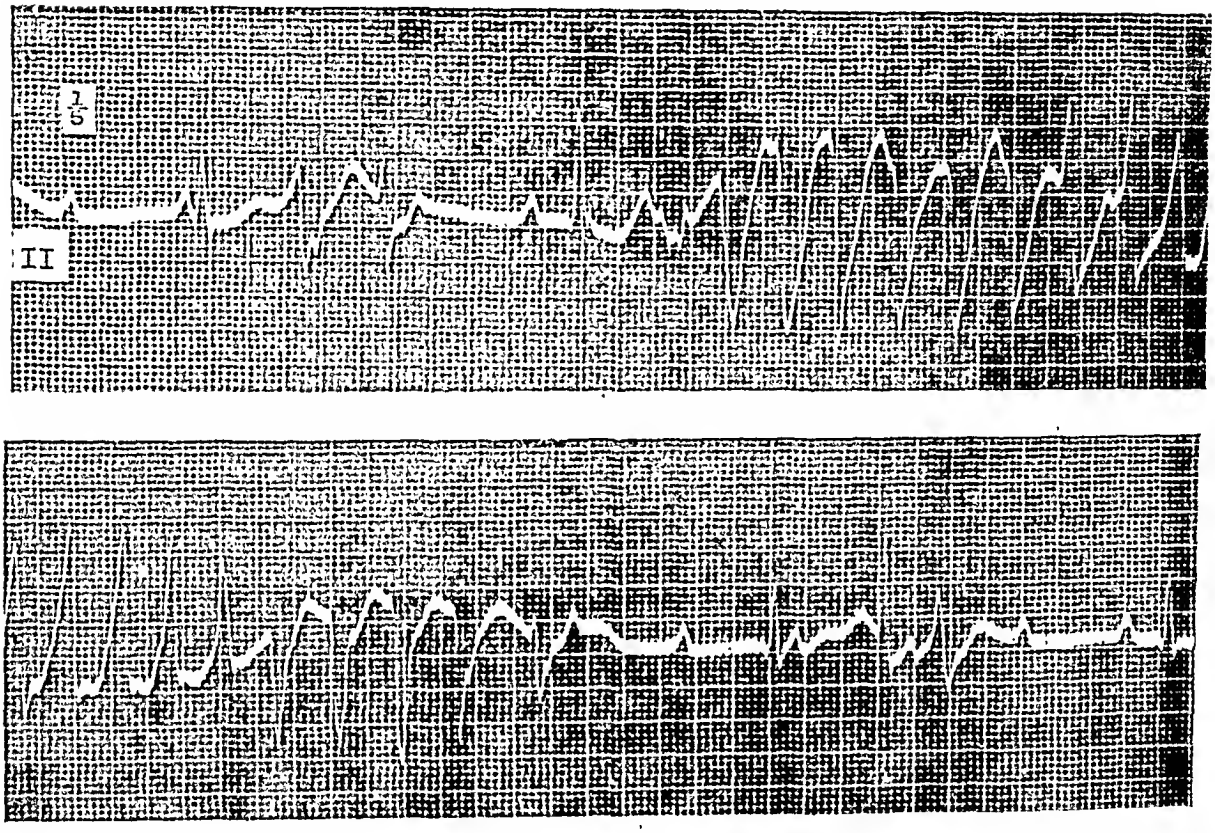

FIG. 11.—Case 8. Stokes-Adams attack. Paroxysm of high ventricular tachycardia (a continuous record has been divided). Complete heart block.

attack. Following the attack of ventricular tachycardia the electrocardiogram was much the same as that preceding it.

The above analysis applies to Fig. 11, taken while the patient was unconscious, and numerous other records were taken, some on continuous strips; they differed only in the duration of the high ventricular tachycardia and were never followed by ventricular standstill. Ventricular fibrillation appeared only in one record taken shortly before death.

DISCUSSION

Ventricular standstill

The attack was preceded in six of the reported cases by an acceleration of the auricular rate, but in many others and in our own case no sufficient record of the phase preceding the attack was available for reckoning. Hay (1921) called attention to " the gradual quickening of the rate of the auricle previous to

ventricular stoppage", and the matter is chiefly discussed by Wenckebach and Winterberg (1927), who found it in all three of their recorded cases, and by Condorelli (1932). As the auricular rate is so closely under nervous control, one might imagine that an increase of the auricular rate from exertion or emotion would often determine attacks. In Case 3 of Wenckebach and Winterberg, the emotion of an arithmetical exercise was observed to quicken the auricles and to cause ventricular standstill; but any such direct relation between exercise and emotion and the attacks must be rare. With the exception of that case, the rise in auricular rate in recorded cases has been spontaneous, and it originates in the auricle itself, probably in the sinus node. An increased auricular rate is known to worsen conduction to the ventricle, but its influence in the production of the standstill is unknown.

During ventricular standstill of short duration (20 seconds or less) auricular activity continues undisturbed or more often at a somewhat higher rate (Cases 2, 3, 4, 5, and 6). The presence of the P waves during ventricular standstill is an important distinction from a common faint, where with slowing there is a total cardiac standstill (Fig. 1). In the longer ventricular standstill of a Stokes-Adams attack the circulatory stasis affects the auricular activity. While the increase of the auricular rate during short ventricular standstill suggests an asphyxial irritation of the sinus node, the decrease of auricular rate after longer ventricular standstill (20 seconds or more) would suggest a subsequent depression in that node. Ectopic P waves may then appear often irregularly (Hermann, Froment, Gonin, & Mahaim, 1937; Géraudel, Laignel-Lavastine, & Boquien, 1933; Heimann, 1929), or P may disappear (Yater & Willius, 1929); alternatively auricular fibrillation and flutter may supervene (Wiltshire, 1923). Irregular and changing P waves have been observed, however, in short ventricular standstill (Cowan & Ritchie, 1935; Norris & Landis, 1938).

The cardiac standstill following a high ventricular tachycardia and fibrillation (Group II (*b*), Case 7) is often total. The effect of the high ventricular tachycardia (V.T.) and ventricular fibrillation (V.F.) on the sinus node is comparable with that of ventricular standstill, as the cardiac circulation is practically arrested. The occasional ectopic P waves seen in Fig. 9D (Case 7), is one effect of auricular stasis, and this and other effects of it are reported by Clerc and Lévy, Case 2 (1936), by Soulié (1938), and by Froment and Gonin (1938*a*), all with ventricular tachycardia and fibrillation (30 seconds or more) preceding the ventricular standstill. Sometimes the auricular rate during ventricular standstill (following high V.T. and V.F.) is accelerated (Lian & Deparis, 1934; Norris & Landis, 1938), and sometimes it is reduced (Gertz, Kaplan, Kaplan, & Weinstein, 1938).

Ventricular Tachycardia

A low ventricular tachycardia may *follow* ventricular standstill, but these cases are classed with Group I (Case 5). In our Case 6 (Group II (*a*)) it preceded ventricular standstill, increasing gradually from 55 to 75. The electrocardiograms between the attacks showed multiform and variable extrasystoles and varying bundle branch block (cf. Cohn & Lewis, 1913; and

Bain, 1941). Such aberrant complexes sometimes replaced the basic ventricular complexes at the low basic rate; at other times they composed a low ventricular tachycardia, with complexes like the extrasystole that followed the basic complex in fixed coupling. The same relation has been deseribed by Herapath (1926) and others. This low ventricular tachycardia may be perceived by the patient as palpitation, as in Case 6, where it was the clear warning of the imminence of unconsciousness due to ventricular standstill.

Whether accompanied or not by ventricular standstill, a close affinity exists between the low and the high types of ventricular tachycardia. They often appear together or follow each other as in our Case 7, and in many of the published cases (see Tables II and III). We divided Group II into (*a*) and (*b*), because low ventricular tachycardia (up to 160) does not produee unconsciousness, but *precedes* a ventricular standstill that does; whereas high ventricular tachycardia with or without ventricular fibrillation does produce unconsciousness. The high ventricular tachycardia differs little from the low in the electrocardiogram, having regard to the rate whieh gives the undulations a less individual character. Any resemblanee to aurieular flutter is quite superficial, and there seems no fundamental reason for assuming a corresponding ventricular flutter with a distinetive mechanism as did De Boer (1923), and later Dressler (1929) and Scherf and Boyd (1940).

Ventricular Fibrillation

Confusion still exists between the high ventrieular taehyeardia and ventricular fibrillation. Yet, though either may follow the other—and the passage may be a gradual one—the electrocardiographic features are very different. The deflections of ventricular tachycardia are praetically regular, and any variation in their shape or size occurs in phases. In any attaek the highest rate (200–500) is found at the onset, and towards the end the rate may fall. The rate in ventricular fibrillation may be the same, higher, or even lower, but the deflections are always irregular in time, and constantly varying in shape and size, and so they resemble an artefact rather than a natural electrocardiogram (Fig. 9 A, B).

Schwartz (1936, *a*, *b*) divided the " transient recurrent ventrieular fibrillation " (comprising the high ventricular tachycardia and ventricular fibrillation) into a pre-fibrillatory, fibrillatory, and post-fibrillatory period. The pre-fibrillatory period is one with multiple and variable extrasystoles and slower ventricular tachycardia (the auricles accelerating), and sometimes with a step-like increase of both auricular and ventricular rates with abrupt changes from partial to complete heart block. The fibrillatory period is that " resembling " ventricular tachycardia (i.e. the high ventricular tachycardia) and the phase of varying, irregular complexes (i.e. ventricular fibrillation). The post-fibrillatory period is the ventricular standstill that may last from 1 or 2 seconds (our Group III, here regarded merely as the expected pause after a paroxysm) to 20 or even 80 seconds (our Group II (*b*)), and the subsequent low ventricular tachycardia.

The instability and variability of the widened bundle branch block com-

plexes and of the associated extrasystoles pave the way for the installation of a new rhythm, which supersedes the A-V pacemaker and rules by its higher rate (low or high ventricular tachycardia or ventricular fibrillation). It is supposed that exhaustion of the new centres causes ventricular standstill during which they may recover some activity (post-fibrillatory ventricular tachycardia) until their final suppression by the basic rhythm.

The Stokes-Adams attack due to the high ventricular tachycardia (and ventricular fibrillation), and that due to ventricular standstill can only be recognized and distinguished by electrocardiogram, because the pulse and the heart sounds are absent in both varieties, and tachycardia may precede each (cf. Groups II and III). Although loss of consciousness of more than three minutes duration points to the high ventricular tachycardia (and fibrillation), our Case 3 with frequently recurring short attacks of ventricular standstill was barely conscious for hours. A late onset of unconsciousness, say that exceeding 20 seconds after the disappearance of the pulse and the heart sounds, is the rule in ventricular tachycardia (and fibrillation) according to Schwartz (1936*a*). But unconsciousness in ventricular standstill may certainly be delayed for over 10 seconds (Cases 1 and 4); and short attacks of ventricular tachycardia (6 seconds in Case 8), if repeated, may induce long periods of unconsciousness. Again, though circulatory arrest is the most important determining factor in the duration of unconsciousness, other factors may contribute, e.g., the rapidity of onset of block and the fall in rate, the frequency of the attacks, a low blood pressure (as after cardiac infarction), and the state of the cerebral arteries. Such being the situation, it is difficult to state the duration of circulatory arrest that produces syncope or convulsions, especially now we know that Stokes-Adams attacks are not due simply to ventricular standstill, and that tachycardia as well as standstill may be in operation. Though admittedly approximate, the onset of unconsciousness in ventricular standstill is given by Mackenzie (1925) as after 10 seconds, and of convulsions as after 15 seconds; by Lewis (1925) as 3–5 and 15–20 seconds; and by Froment and Gonin (1938*b*) as 5–15 and 30–45 seconds respectively.

The electrocardiogram of the Stokes-Adams attack under special conditions.

The grade of heart block between the attacks, whether *partial* or *complete*, has no bearing upon the electrocardiographic features of the attack. Our Groups I, II, and III contain an almost equal number of both grades.

Among 10 cases of *paroxysmal heart block*, the attack was due to ventricular standstill alone (Group I) in 8 (Yates and Willius, 1929; Cheer and T'ang, 1932; Sachs and Traynor, 1934; Schwartz, 1936*c*; Hermann, Froment, Gonin, and Mahaim, 1937; Sigler, 1939*a*; Teran, 1941; our Case 4, Fig. 6). In one the ventricular standstill was preceded by the low ventricular tachycardia (Group II (*a*)) (Gager and Pardee, 1925), and in the remaining case it was preceded by the high ventricular tachycardia (Group II (*b*)) (Gertz, Kaplan, Kaplan, and Weinstein, 1938). Thus ventricular standstill seems to be the usual basis of the Stokes-Adams attack in paroxysmal block. Comeau (1937) has discussed paroxysmal heart block as a whole.

No actual electrocardiogram of a Stokes-Adams attack in *congenital heart block* has been found, though Fæssler (1939) has collected 8 such reported cases, and 6 had established complete heart block between the attacks. In his own case there was no block, but nodal rhythm during the unconsciousness.

The incidence of heart block in *coronary thrombosis* is given as 7·6 per cent Kerr (1937), and as 3·2 per cent by Master, Dack, and Jaffe (1938). One of Kerr's 12 cases had Stokes-Adams attacks; and 3 of the 5 cases of Master, Dack, and Jaffe were comatose or semi-comatose, though without distinctive Stokes-Adams attacks. Among 45 cases with Stokes-Adams attacks, 15 were due to posterior coronary thrombosis according to Schwartz (1936*b*). Among the cases we have collected, recent coronary thrombosis was present in 6. In 3 (Laufer, 1934; Schwartz, 1936*b*; Scherf & Boyd, 1940) the Stokes-Adams attack was due to ventricular standstill (Group I), in 2 (Freundlich, 1932; Soulié, 1938) it was due to ventricular tachycardia and fibrillation with standstill (Group II (*b*)), and in 1 (Sigler, 1939*b*) to ventricular tachycardia and fibrillation (Group III). Except in Soulié's case (with variable bundle branch block), the electrocardiogram was of the T_3 type. Although no statistical conclusions can be drawn from 6 cases, it is evident that Stokes-Adams attacks in coronary thrombosis may be due to ventricular standstill, to ventricular tachycardia and fibrillation, or to these combined, and that all are not due to ventricular fibrillation.

Prognosis

The nature of the electrocardiogram during attacks has a great influence upon the prognosis, and this is evident from the 35 cases that were followed up; 15 belong to Group I (ventricular standstill alone) and 20 to Groups II and III (low or high ventricular tachycardia and fibrillation, followed or not by ventricular standstill). Among the 15 of Group I, 5 died during the observed attack and 7 were alive and attack free over a period of from three months to four and a half years; in 3 death was due to other than heart conditions (cerebral thrombosis, peritonitis, and spinal tumour). Among the 20 of Groups II and III, 16 died in an attack (11 during the observed attack and 5 within a year of discharge from hospital), and only 4 were alive at the end of three to ten months. It follows that patients showing ventricular standstill alone have a fair chance of recovery even after severe Stokes-Adams attacks, but that when the attacks include the low or high ventricular tachycardia (and fibrillation) the immediate prospect of recovery is far worse, and even if they recover they seldom survive for more than a year.

SUMMARY

Stokes-Adams disease is a name applicable to patients with heart block who suffer from recurrent attacks of loss of consciousness due to ventricular standstill, ventricular tachycardia, ventricular fibrillation, or a combination of these.

During a Stokes-Adams attack from ventricular standstill the auricle con-

tinues to beat, whereas in cardiac syncope of other types there is as a rule total cardiac standstill.

Cardiac syncope of neurogenic origin (e.g. ordinary fainting, and ventricular standstill from disease affecting the vagus or carotid sinus) and cardiac syncope of myocardial origin without heart block (e.g. in nodal bradycardia and in paroxysmal ventricular tachycardia) are excluded by this definition, though there are borderline cases.

(2) The cardiac mechanism of Stokes-Adams attacks was studied on electrocardiograms recorded during the period of unconsciousness, in 8 of our own cases and in 56 reported cases. These fall into four groups or types and are tabulated according to the electrocardiographic basis of the attack.

Group I (28 reported cases and 5 of our own) includes those with *ventricular standstill alone* (Table I).

Group II (16 reported cases and 2 of our own) includes both those with (a) *low ventricular tachycardia* and (b) *high ventricular tachycardia and fibrillation, when either is followed by ventricular standstill* (Table II).

Group III (12 reported cases and 1 of our own) includes those with the high *ventricular tachycardia and fibrillation* without ventricular standstill (Table III).

Group IV includes those rare cases with *extreme bradycardia in heart block* (no Table).

It is evident that ventricular standstill alone is not the only cardiac lapse that determines a Stokes-Adams attack. It is often due to ill action, not to inaction of the ventricle. Ventricular standstill is responsible for about 55 per cent ; ventricular tachycardia (with or without ventricular fibrillation), followed by ventricular standstill, for 25 per cent; and ventricular tachycardia without ventricular standstill for 20 per cent.

(3) *Ventricular standstill* is sometimes consecutive to a rise in the auricular rate. As exertion or emotion so seldom determines ventricular standstill, this increase in the auricular rate probably originates locally in the auricle and not from any nervous influence.

During a short ventricular standstill (below 20 seconds), the auricle beats regularly, often at an increasing rate, and the persistence of P waves during the ventricular standstill is a feature distinguishing it from the total standstill of cardiac syncope. During a long ventricular standstill (above 20 seconds), or when ventricular standstill is preceded by high ventricular tachycardia and fibrillation (Group II), the auricle may show slower, irregular, and ectopic P waves, auricular fibrillation and flutter, or it may even stop.

(4) In the group with *ventricular tachycardia*, multiple and variable extrasystoles and varying bundle branch block complexes between the attacks are common, as might be expected. Low ventricular tachycardia (up to 160) does not produce unconsciousness, but it provokes the subsequent ventricular standstill that does produce it (Group II (*a*)). High ventricular tachycardia and fibrillation (200–500) produce unconsciousness (Group III), and this may be prolonged by the subsequent ventricular standstill (Group II (*b*)). The electrocardiogram of ventricular tachycardia is composed of regular deflections like bundle branch block, which at high rates merge into simple undulations;

yet the term " ventricular flutter " need not be used, for the resemblance to auricular flutter is superficial.

(5) *Ventricular fibrillation* is distinguished from ventricular tachycardia by its irregularity both in rate and in form, though the rate per minute may be the same, higher, or even lower. High ventricular tachycardia easily passes into fibrillation, which ends with ventricular standstill or with gradual resumption of the basic rhythm through a period of low ventricular tachycardia or of varying extrasystolic complexes.

(6) The essential basis of an attack can only be decided by electrocardiogram. The prolongation of unconsciousness or its late onset in ventricular tachycardia and fibrillation cannot distinguish this group from that of ventricular standstill alone, because other factors may influence unconsciousness, e.g., the suddenness of the development of block or of the fall in rate, a rapid succession of attacks, and the state of the cerebral arteries. For similar reasons it is difficult to state exactly what must be the duration of the circulatory arrest to produce syncope or convulsions.

(7) In established complete heart block or in partial heart block the Stokes-Adams attack may belong to any group, whereas in paroxysmal heart block it is generally in Group I, i.e., ventricular standstill alone. After coronary thrombosis, attacks due to ventricular standstill alone may occur, as well as those due to ventricular tachycardia and fibrillation.

(8) No prognostic significance can be attached to the grade of heart block, partial or complete, obtaining between the attacks, but the electrocardiographic nature of the attack has great significance in prognosis—and doubtless in treatment, though this is not here considered. Patients with ventricular standstill (Group I) have a fair chance of recovery and often survive for many years, whereas those with ventricular tachycardia and fibrillation (Groups II and III) seldom recover and then rarely survive for more than a year.

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REFERENCES

Adams, R. (1827). *Dublin Hosp. Reports*, **4**, 353.
Allan, G. A. (1926). *Glasgow Med. J.*, **105**, 440.
Bain, C. W. C. (1941). *Brit. Heart J.*, **3**, 75.
Bizzozero, R. C. (1934). *Rev. Argent. Cardiol.*, **1**, 371.
Burnett, W. (1827). *Trans. Med. Chir. Soc., London*, **13**, 202.
Campbell, M., and Suzman, S. S. (1934). *Amer. Heart J.*, **9**, 304.
Cassidy, M. (1928). *Proc. Roy. Soc. Med.*, **21**, 762.
—— and Page, C. Max. (1928). *Proc. Roy. Soc. Med.*, **21**, 1414.
Cheer, S. N. and T'ang, T. K. (1932). *Chinese Med. J.*, **46**, 1081.
Clerc, A. and Lévy, R. (1936). *Arch. Mal. Cœur*, **29**, 307.
Coelho, E. (1932). *Ibid.*, **25**, 232.
Cohn, A. E. and Lewis, T. (1913). *Heart*, **4**, 15.
Comeau, W. J. (1937). *Amer. J. med. Sci.*, **194**, 43.
Condorelli, L. (1932). *Arch. per le Scienze med.*, **56**, 661.
Cotton, F. F. and Lewis, T. (1918). *Heart*, **7**, 23.
Cossio, P. (1939). *Aparato Circulatorio*, 2nd ed., Buenos Aires.
Cowan, J. and Ritchie, W. T. (1935). *Diseases of the Heart*, 3rd ed., London.
De Boer, S. (1923). *Z. ges. exper. Med.*, **38**, 191.

Downie, E. (1929). *Med. J. Austral.*, **1**, 822.
Dressler, W. (1929). *Klin. Woch.*, **1**, 165.
Dubbs, A. W. (1938). *Amer. Heart J.*, **16**, 235.
Fæssler, B. (1939). *Ann. Pædiatr.*, **153**, 327.
Fishberg, A. M. (1940). *Heart Failure*, 2nd ed., London.
Freundlich, J. (1932). *Disch. Arch. klin. Med.*, **173**, 617.
Froment, R., and Gonin, A. (1938*a*) *Arch. Mal. Cœur.*, **31**, 645.
—— —— (1938*b*) *Paris Méd.*, **28**, 375.
Gager, L. T., and Pardee, H. E. B. (1925), *Amer. J. med. Sci.*, **169**, 656.
Gaillard, Ch. (1922–23). *Syndrome de Stokes-Adams, Thèse de Lyon.*
Gallavardin, L., and Berard, A. (1924). *Arch. Mal. Cœur*, **17**, 18.
—— and Froment, R. (1932). *Ibid.*, **24**, 670.
Géraudel, E., Laignel-Lavastine, P. M., and Boquien, Y. (1933). *Ibid.*, **26**, 1.
Gertz, G., Kaplan, H. A., Kaplan, L., and Weinstein, W. (1938). *Amer. Heart J.*, **16**, 225.
Gilchrist, A. R. (1934). *Brit. Med. J.*, **1**, 610.
Gluch, B. (1932). *Zeitschr. f. Kreislauf.*, **24**, 561.
Graybiel, A., and White, P. D. (1936). *Amer. J. med. Sci.*, **192**, 334.
Grœdel, F. M., and Kisch, B. (1939). *Cardiologia*, **3**, 301.
Hay, J. (1921). *Graphic Methods in Heart Disease*, 2nd ed., London.
Heimann, H. L. (1929). *Lancet*, **1**, 68.
Herapath, C. E. K. (1926). *Ibid.*, **1**, 653.
Hermann, H., Froment, R., Gonin, A., and Mahaim, I. (1937). *Arch. Mal. Cœur*, **30**, 753.
Holberton, T. H. (1841). *Trans. Med. Chir. Soc., London*, **24**, 76.
Hœsslin, H. (1925). *Klin. Woch.*, **1**, 62.
Huchard, H. (1899). *Traité clinique des Maladies du Cœur et de l'Aorte*, 3rd ed., Paris, Vol. I.
Jezer, A., Master, A. M., and Schwartz, S. P. (1936). *Amer. Heart J.*, **11**, 303.
Kahall, W. L. (1935). *J. Amer. med. Assoc.*, **105**, 2054.
Kerr, O. (1937). *Lancet*, **2**, 1066.
Kerr, W. J., and Bender, W. L. (1922). *Heart*, **9**, 269.
Laplace, L. B. (1939). *Internat. Clin.* **1**, 180.
Laufer, S. (1934). *Wien. Arch. inn. Med.*, **26**, 21.
Levine, S. A., and Matton, M. (1926). *Heart*, **12**, 271.
Levy, R. C. (1939). *Ann. intern. Med.*, **12**, 1525.
Lewis, T. (1925). *The Mechanism and Graphic Registration of the Heart Beat*, 3rd ed., London.
Lian, C., and Deparis, M. (1934). *Bull. Mém. Soc. méd. Hôp.*, Paris, No. 13.
Lukl, P. (1937). *Casopis lékarn ceskych*, **76**, 780.
Mackenzie, J. (1925). *Diseases of the Heart*, 4th ed., London.
Master, A. M., Dack, S., and Jaffe, H. L. (1938). *Amer. J. med. Sci.*, **196**, 513.
Mayo, H. (1838). *Lond. med. Gaz.*, **22**, 232.
Norris, G. W., and Landis, H. R. M. (1938). *Diseases of the Chest and the Principles of Physical Diagnosis*, 6th ed., Philad. and London.
Pardee, H. E.B. (1933). *Clinical Aspects of the Electrocardiogram*, 3rd ed., New York.
Sachs, A., and Traynor, R. L. (1934). *Amer. Heart J.*, **9**, 267.
Scherf, D., and Boyd, L. J. (1940). *Clinical Electrocardiography*, London.
Schwartz, S. P. (1936*a*). *Amer. J. med. Sci.*, **192**, 153 and 808.
—— (1936*b*). *Amer. Heart J.*, **11**, 554.
—— and Hauswirth, L. (1934). *Amer. J. med. Sci.*, **187**, 478.
—— and Jezer, A. (1932). *Arch. intern. Med.*, 50, 450.
—— —— (1934). *Amer. J. med. Sci.*, **187**, 469.
Sigler, L. H. (1938). *Amer. Heart J.*, **16**, 109.
—— (1939*a*). *Ann. intern. Med.*, **13**, 101.
—— (1939*b*). *Internat. Clin.*, **1**, 221.
Soulié, P. (1938). *Arch. Mal. Cœur.*, **31**, 111.
Spens, T. (1793). *Med. Comment. Edinburgh, decade* 2, **7**, 458.
Spühler, O. (1936). *Z. klin. Med.*, **129**, 693.
Stecher, R. M. (1928). *Amer. Heart J.*, **3**, 567.
Stokes, W. (1846). *Dublin Quart. J. Med. Sci.*, **2**, 73.
Teran, V. S. (1941). *Revista argent. Cardiol.*, **7**, 374.
Turrey, R. G., and Leaman, W. G. (1939). *Trans. Coll. Phys. Philad.*, **6**, 336.
Weiss, S. and Baker, J. P. (1933). *Medicine*, **12**, 297.
—— and Ferris, E. B. (1934). *Arch. intern. Med.*, **54**, 931.
Wenckebach, K. F., and Winterberg, H. (1927). *Die unregelmässige Herztätigkeit*, Leipzig.
Wilson, F. N., and Robinson, G. C. (1918). *Arch. intern. Med.*, **21**, 181.
Wiltshire, H. (1923). *Heart*, **10**, 201.
Wood, J. E. (1932). *J. Amer. med. Ass.*, **1**, 1364.
Yater, W. M., and Willius, F. A. *Amer. Heart J.*, **4**, 280.

TOTAL THYROIDECTOMY FOR HEART FAILURE: AN UNUSUAL CASE

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Congestive cardiac failure associated with thyrotoxicosis is almost always relieved by sub-total thyroidectomy. It is probable that the improvement in the cardiac condition can be attributed to two distinct factors: first, to the removal of a direct toxic action of the thyroid secretion on the heart, and, secondly, to the removal of the burden of an augmented circulation rate that the increased metabolism of thyrotoxicosis places upon the heart. The direct effect of the thyroid on the heart is evident in the common association of auricular fibrillation with thyrotoxicosis and in the frequency with which normal rhythm is restored in such cases after sub-total thyroidectomy. The close connection between thyrotoxicosis and auricular fibrillation is also seen in the common occurrence of the latter in the first two days after thyroidectomy —a time when all the manifestations of thyrotoxicosis are generally at their height.

The effect of thyroidectomy in sparing the work of the heart has been most fully demonstrated by the work of Blumgart, Levine, Berlin, and their colleagues on total thyroidectomy for non-thyrotoxic heart disease. In a series of papers (summarized by Blumgart *et al.* 1933) they showed that in the absence of cardiac failure the circulation rate in normal subjects and in cases of thyrotoxicosis and of myxœdema was adjusted in proportion to the metabolic rate. When heart failure is present, however, this relationship breaks down, so that in the ordinary cases of congestive heart failure, although the basal metabolic rate is normal, the circulation rate is no greater than in a case of myxœdema without heart failure. Similarly, in cases of thyrotoxicosis with heart failure, the circulation rate is less than in other such cases without heart failure. On the basis of these findings, they put forward the practical suggestion that in congestive cardiac failure the lost equilibrium between circulation rate and metabolic rate could be restored by reducing the latter to the level of the former by total thyroidectomy. Although the measure of success achieved by this therapy is still in dispute, it seems clear from the work of Blumgart and his colleagues, and those who have repeated it, that cases of congestive cardiac failure can sometimes be improved by total thyroidectomy; and that such improvement,

when it occurs, is brought about by diminishing the work the heart has to do rather than by increasing its capacity to do it.

We are reporting here the case of a patient in whom the removal of a normal thyroid gland was followed not only by the relief of cardiac failure but also by the disappearance of auricular fibrillation. It seems to us improbable that the abolition of auricular fibrillation can be attributed merely to the lowering of the metabolic rate, and we feel bound to postulate in this patient a direct action of the normal thyroid gland on the heart. However it was brought about, there can be no doubt that total thyroidectomy proved to be a most successful form of therapy, and one which might be worth trying in similar cases.

The patient was a man, aged 51, at the time of operation. He was first admitted to University College Hospital under Dr. Kenneth Harris in 1931, at the age of 43, with a history of breathlessness and swelling of the legs for four weeks. There was no history of rheumatic fever. On admission, he was found to be in congestive cardiac failure; the heart rate was 160–180 and the rhythm regular. A cardiogram showed auricular flutter. He was given digitalis in full doses; the rhythm became normal on the seventh day and the signs of congestive failure then quickly disappeared. He left hospital with a heart of normal size (orthodiagram) and a regular heart rate of 70–86.

He then continued at full work (clerical), with occasional attacks of palpitation as the only symptom, until Christmas 1938, when severe palpitation developed, leading to his readmission to hospital four weeks later. He then showed signs of early congestive cardiac failure; the heart rate was 140–170 and the rhythm grossly irregular. A cardiogram confirmed the diagnosis of auricular fibrillation. There were no signs of valvular damage. He was treated with digitalis; the heart rate was reduced to 84–96 and the signs of congestive failure disappeared; but auricular fibrillation persisted.

He was, however, unable to return to work, and when seen in March 1939 fibrillation was still present and the heart rate was 148. In May 1939, he was readmitted in congestive cardiac failure. The heart rate was 100–140 and auricular fibrillation was still present (confirmed by cardiogram). The heart was considerably enlarged. He was given digoxin intravenously, and thereafter by mouth. In three weeks the signs of congestive failure had disappeared and the heart rate was 80–96. He was specifically examined at this time for signs of thyrotoxicosis; but none were found.

At this point Dr. Harris advised a total thyroidectomy, and on June 1, 1939, this was performed under local anæsthesia by Mr. Julian Taylor. The post-operative course was uneventful, except for the occurrence of attacks of tetany on the eighth, tenth, and thirteenth days; these were easily controlled by injections of calcium gluconate and by calciferol by mouth. On the thirteenth day after operation the heart returned to normal rhythm (confirmed by cardiogram): this persisted for the rest of his stay in hospital, the rate being 68–76. The heart returned to normal size. He was given no thyroid extract, but calciferol was continued to control the tetany.

When next seen, at the end of July, he was back at full work, and the rhythm was still regular. In September, he was still at work, though somewhat easily tired. The heart rate was 82, and regular. So far he had had no thyroid extract, and by this time the signs of myxœdema were obvious and appeared to be troubling him. Tab. thyroid sicc. (B.P.) was therefore started in doses of 1·0 gr. daily.

In October the heart was still regular and the rate 84. The dose of thyroid was now increased to 1·5 gr. daily and maintained at this level till January 8, 1940. In November 1939 he had an attack of tachycardia with irregular rhythm which lasted several hours. In December there were several similar attacks. On January 8 he was seen in an attack of tachycardia; the rhythm being regular and the rate 160. It was presumed

that this was paroxysmal auricular flutter, but a cardiogram could not be taken at that time. The thyroid extract was then stopped. A week later he was seen again. This time auricular fibrillation was present, the heart rate being 110. Two days later the heart became regular again and tachycardia ceased. One further attack with irregular heart action occurred on January 21; but it proved to be the last.

By March he had been without thyroid extract for ten weeks and the symptoms of myxœdema had become troublesome again. He was therefore restarted on 0·5 gr. daily. This proved to be enough to keep the symptoms of myxœdema at bay. He has been seen at regular intervals for a year since restarting thyroid extract and there has never been any suggestion of a recurrence of the paroxysmal flutter or fibrillation. He has been at full work during this period, and recently has been fire-watching as well. He was anxious to join the Pioneer Corps, but was advised not to do so. He is able to take a normal amount of exercise without becoming breathless.

The thyroid gland from this patient weighed 20 g., which is within normal limits for this country. It was normal in appearance, both macroscopically and microscopically. The Golgi apparatus in the cells lining the vesicles was not enlarged.

Discussion

It will be seen that this case differs from those recorded by Blumgart and his colleagues in that total thyroidectomy not only relieved congestive cardiac failure but also restored the heart to normal rhythm. In fact, the removal of a normal thyroid in this case had the same effect as the removal of an abnormal thyroid in a case of thyrotoxicosis. This similarity is the more striking in that in our case normal rhythm returned on the thirteenth day after operation; it is at about this time that auricular fibrillation commonly disappears after thyroidectomy in thyrotoxic cases. Moreover, in our case, as in many cases of thyrotoxic heart disease, cardiac failure only appeared when uncontrolled auricular flutter or fibrillation was present; and it disappeared promptly whenever the heart rate was brought under control. Cardiac failure was dependent on the presence of the disorder of rhythm. In Blumgart's cases, on the other hand, auricular fibrillation was not abolished by total thyroidectomy, and cardiac failure was relieved in spite of the persistence of the disorder of rhythm.

These facts made us consider the possibility that our case was in fact one of thyrotoxicosis. But in our opinion the finding of a thyroid of normal size and normal histological structure excludes this.

If we accept this conclusion, we are faced with the surprising conclusion that thyroidectomy in a man with normal thyroid function has had the same effect on the heart as thyroidectomy in a case of thyrotoxicosis. Our suggested explanation is based on the widely held opinion (Lahey, 1929; Hurxthal, 1931; Lewis, 1931; Andrus, 1932; Rosenblum and Levine, 1933; Mayer and Sittler, 1936; Means, 1937; and Gotta, 1938) that thyrotoxic heart failure is due to a combination of two factors—a primary cardiac disorder and thyroid toxæmia. On this view, thyrotoxicosis cannot by itself cause cardiac failure: it can only make manifest a cardiac disorder that would otherwise remain latent. If we accept the existence of such latent cardiac disorders, it is not difficult to imagine that similar conditions of the heart might exist that are manifest at a normal level of thyroid function but become latent at a low level. This interpretation is supported by our experience of a case of toxic nodular goitre, in which sub-

total thyroidectomy was followed by the disappearance of auricular fibrillation and later by the development of myxœdema; doses of thyroid extract sufficient to relieve the symptoms of myxœdema led to the reappearance of auricular fibrillation. Swan (1924) had a similar experience. It will be recalled that the patient described here behaved in a similar way, developing paroxysmal auricular fibrillation on 1·5 gr. of thyroid extract a day, but not on 0·5 gr. a day. The behaviour of these cases suggests that, in a suitably predisposed heart, auricular fibrillation may be precipitated not only by excessive amounts or by an abnormal type of thyroid hormone but also by the normal hormone in normal quantities.

If this interpretation is correct, then the success of thyroidectomy in our case was due not, as in Blumgart's cases, to a reduction in the work which the heart had to do but to the removal of an agent injurious to the heart. As thyroid extract in full dosage caused the reappearance of auricular fibrillation and omission of the extract was followed by a return to normal rhythm, this agent is presumably the thyroid secretion itself. These considerations make it important to define as far as possible the type of case in which a similar result is likely to be obtained. Among the cases with auricular fibrillation described by Blumgart *et al.* (1935) there is no record of any in which normal rhythm was restored after total thyroidectomy. All these cases had long histories of cardiac disease and all showed evidence of structural damage of the heart. It seems likely, therefore, that the abolition of auricular fibrillation will not be achieved when it has been long in existence or where it is accompanied by structural damage of the heart. This conclusion is borne out by the experience of Rosenblum and Levine (1933) in cases of thyrotoxicosis with heart failure. They found that of 11 cases with auricular fibrillation and mitral stenosis, only 1 returned to normal rhythm after sub-total thyroidectomy; whereas of 6 cases with auricular fibrillation without evidence of structural damage to the heart, all 6 returned to normal rhythm. Furthermore, the only report of cases similar to ours that we have been able to discover is that of Singer (1937); in both of his cases paroxysmal auricular fibrillation disappeared after total thyroidectomy. Therefore, it seems that the type of case likely to benefit from total thyroidectomy in the way ours has done is one in which auricular fibrillation or flutter is either paroxysmal or not of long duration, and there is no evidence of structural damage of the heart. Such cases are usually regarded as suitable for quinidine therapy; but it may be found that in some instances total thyroidectomy is a more stable and satisfactory alternative. The mortality from the operation is likely to be small, for Berlin's (1935) last 62 total thyroidectomies were performed without fatality, although his cases had gone through long periods of congestive cardiac failure and were therefore poorer operative risks than the type of case we have in mind.

Summary

A case has been described in which the complete removal of a normal thyroid gland was followed by the disappearance of auricular fibrillation and

congestive cardiac failure. Auricular fibrillation reappeared when the patient was given 1·5 gr. of thyroid extract daily, but disappeared again when the dose was reduced to 0·5 gr. daily.

It is suggested that in this case the normal thyroid hormone had the same effect on the heart as has the excessive or abnormal secretion in cases of thyrotoxicosis.

It is suggested that cases of auricular fibrillation or flutter, in which the disorder of rhythm is either paroxysmal or of short duration and there is no evidence of structural damage to the heart, might be expected to benefit in a similar way as the result of total thyroidectomy.

References

Andrus, E. C. (1932). *Trans. Ass. Amer. Phys.*, **47**, 47.
Berlin, D. D. (1935). *J. Amer. med. Ass.*, **105**, 1104.
Blumgart, H. L., Berlin, D. D., Davis, D., Riseman, J. E. F., and Weinstein, A. A. (1935). *Ibid.*, **104**, 17.
Blumgart, H. L., Riseman, J. E. F., Davis, D., and Berlin, D. D. (1933). *Arch. intern. Med.*, **52**, 165.
Gotta, G. (1938). *Ibid.*, **61**, 860.
Hurxthal, L. M. (1931). *Ibid.*, **47**, 167.
Lahey, F. H. (1929). *Ann. Surg.*, **90**, 750.
Lewis, W. (1931). *Amer. J. med. Sci.*, **181**, 65.
Mayer, C. C., and Sittler, W. W. (1936). *J. Amer. med. Ass.*, **106**, 1546.
Means, J. H. (1937). *The Thyroid and its Diseases*, p. 429.
Rosenblum, H. H., and Levine, S. A. (1933). *Amer. J. med. Sci.*, **185**, 219.
Singer, R. (1937). *Wien. Klin. Woch.*, **50**, 1025.
Swan, J. M. (1924). *Ann. Clin. Med.*, **3**, 311.

COARCTATION OF THE AORTA: THE COLLATERAL CIRCULATION

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Coarctation of the aorta imposes a mechanical embarrassment on the circulation and so affords an opportunity of studying problems of both clinical and physiological interest. During the past ten years we have had the good fortune to meet with thirteen patients exhibiting this abnormality, and in the present and future papers it is our object to consider some of the problems presented by this condition.

This paper is concerned with one of our patients in whom the lesion was diagnosed in 1938. Two years later she was admitted to hospital suffering from subarachnoid hæmorrhage, from which she died. This accident gave us the opportunity of studying the collateral circulation, in a patient who exhibited no signs of heart failure, by a method to which we have been able to find only one reference (Ernstone and Robins, 1931). We injected the arterial system with barium paste and took a series of radiograms of the cadaver.

CASE RECORD

A nulliparous woman, aged 25, consulted one of us (C. B.) in July 1938 regarding her fitness for pregnancy.

Following rheumatism at the age of 5, a heart murmur had been discovered. At 7 years she was troubled by growing pains. She suffered from chilblains and from cold hands and feet. At school she was never able to play games, and at the age of 15 was off school for a year with dyspnœa and palpitation. In childhood she suffered from migraine, which occurred almost every week and was associated with vomiting and severe bilateral frontal headache; this ceased in adult life. Between the ages of 17 and 24 she worked in an office, and during this period was never absent owing to illness. She gave up this work on marriage, nine months before we saw her.

At that time her chief complaints were of pain below the left scapula, which became worse on exertion, and of occasional dyspnœa, palpitation, and flatulent dyspepsia. Nevertheless she was able to do all her own housework with the help of a woman on one half-day each week.

On physical examination the first thing that struck one was the violent arterial pulsation in the neck. The pulse rate was 112 and its rhythm regular; the blood pressure was 235/100 in both arms. On auscultation there was a systolic murmur with an unusual distribution; it was heard both at the apex and at the base of the heart, but was loudest on the back of the chest on the right side, just above the spine of the scapula. The femoral pulse was of small volume, and the systolic blood pressure at the ankle was 140.

A diagnosis of coarctation of the aorta was made, and was confirmed by radiography (Fig. 1–3). This showed the characteristic notching of the ribs and the absence of the aortic knuckle (Fig. 1); and, in the right oblique position, the absence of the typical aortic impression on the barium-filled œsophagus (Fig. 2). In the electrocardiogram the T wave was diphasic in lead II and negative in lead III. A blood count showed hypochromic anæmia with 70 per cent hæmoglobin. The urine contained a trace of albumin; the specific gravity was 1018 and the renal function tests were satisfactory.

Apart from the pain in the back she remained fairly well until the morning of July 30, 1940, when suddenly she was seized by a severe pain in the occipital region; this spread down the back to the legs. She vomited four or five times, became semi-conscious, and subsequently spoke only once to complain of very severe headache. On admission to the Manchester Royal Infirmary that afternoon she was comatose, with signs of severe meningeal irritation. Her pulse was 80, full and bounding, and her blood pressure was 220/115. The left arm and leg were more flaccid than the right, and the left plantar response was extensor. The condition was diagnosed as subarachnoid hæmorrhage, and this diagnosis was confirmed by the withdrawal of a heavily blood-stained cerebrospinal fluid under increased pressure. She died a few hours later.

Post-mortem Examination

(a) *Morbid Anatomy.* An autopsy was performed by Dr. W. Susman seventeen hours after death. Apart from œdema of the lower lobes of the lungs and slight generalized passive congestion, the abnormalities found were confined to the brain and cardiovascular system.

The brain weighed 1300 grammes. Blood was present in the subarachnoid space over the right cerebral hemisphere and the pons. A pressure cone was evident and the convolutions were flattened. Most of the outer half of the right parietal lobe had been destroyed by hæmorrhage, and the area was occupied by blood clot; the hæmorrhage had burst into the right lateral ventricle and blood was present in the right lateral, third, and fourth ventricles. In the plane of the pituitary stalk, just below the level of the optic thalamus, there was an aneurysm of the right middle cerebral artery, 0·8 cm. in diameter (Fig. 4). This aneurysm had recently ruptured.

The descending thoracic and the abdominal aorta were rather small. The intercostal arteries, the internal mammary arteries, and the arteries of the head, neck, and upper limbs were enlarged and tortuous.

FIG. 1.—*Teleradiogram of the chest (Postero-Anterior).* The aortic knuckle is not visible, and there is notching of several ribs (see Fig. 17). The heart is not enlarged.

FIG. 2.—*Teleradiogram of the chest in the right anterior (I) oblique position.* There is no typical aortic impression on the œsophagus; the posterior mediastinum is clear, and the œsophagus is not displaced by the left auricle.

FIG. 3.—*Teleradiogram of the chest in the left anterior (II) oblique position.*

FIG. 4.—*Coronal section of the brain.* There is a large hæmorrhage in the right parietal lobe. The ruptured congenital aneurysm has been cut across and is indicated by an arrow. This association of congenital cerebral aneurysms with coarctation of the aorta has been noted by various authors (Brown, 1939).

The aorta appeared to be completely occluded at a point on the arch just distal to the left subclavian and near the entrance of the obliterated ductus arteriosus, which was represented by a stout fibrous strand (Fig. 5). The left subclavian artery arose as a direct continuation of the aortic arch and was unusually large. The upper intercostal arteries, entering the descending aorta just distal to the occlusion, were greatly dilated.

The heart weighed 350 grammes. The specimen, unfortunately, was destroyed, as the result of enemy action, before any further examination had been made.

(b) *Injection of the Arteries.* Prior to autopsy it was decided to attempt to inject the arteries of the intact cadaver with an opaque paste in order to

FIG. 5.—*The heart.* The coarctation is visible just distal to the origin of the left subclavian, which forms the continuation of the aortic arch. The innominate, the left common carotid, the left subclavian, and their branches are greatly enlarged. The upper aortic intercostals are seen cut across and are greatly enlarged. The obliterated ductus arteriosus persists as a fibrous cord.

study the collateral circulation. Barium enema paste was used, as it was readily available at short notice.

An incision was made on the left side of the neck and the left common carotid artery exposed; a canula was introduced and the barium injected slowly into the arch of the aorta, proximal to the coarctation, under radioscopic control. Films were taken at intervals in the anterior and oblique positions (Fig. 6, 7, 9, 10, and 11) and of the abdominal vessels (Fig. 12). It was found best to keep a moderate pressure on the piston of the syringe during the exposure in order to distend the aorta slightly.

It is important to inject the barium under radioscopic control, in order to ensure that sufficient enters the arteries to outline them satisfactorily without obscuring the larger vessels by filling the arterioles and capillaries. Flooding of the vessels occurs earlier in some areas than in others and it is advisable to take a series of films at different stages of the injection in order to display all the main vessels.

Between 700 and 800 c.c. of barium paste were used in this case. The paste used for barium enemata is suitable for this purpose; a thinner paste is liable to cause flooding before the main vessels are satisfactorily outlined.

The barium was injected above the coarctation, and therefore reached the vessels of the lower part of the body by the collateral channels. The descending aorta, the aortic intercostals, and the abdominal vessels were filled in this way. Since the barium followed the path taken by the blood during life, filling artefacts were avoided.

The results of the injection are shown in Fig. 6–11 which follow, and they are explained in the legends below each.

The first two show an early and late stage of the injection in the ordinary antero-posterior position. The injection canula is seen in the left common carotid. In Fig. 6 the intercostal arteries are only beginning to fill, but in Fig. 7 they are well filled and the tortuosities and notching of the ribs are clearly seen. The coarctation can be seen to the left of the mediastinal shadow and in Fig. 7 the tortuous enlarged subscapular artery can be seen on the right border of the chest. Fig. 8 is a tracing from Fig. 7, naming the arteries that can be seen.

Fig. 9 and 10 show the left (II) oblique positions: in both the coarctation is clearly seen and seems to be complete; in the former it is crossed by two tortuous and enlarged aortic intercostals passing upwards to anastomose with the superior intercostal. In Fig. 11 a clear picture has been taken of the main branches above the coarctation and of some from below (shown in darker shading).

Finally, Fig. 12 shows the abdominal vessels, which must have filled entirely through the collateral circulation, although the well-known anastomosis between the superior and deep epigastric arteries was not developed in this case. The legends below each figure give fuller details.

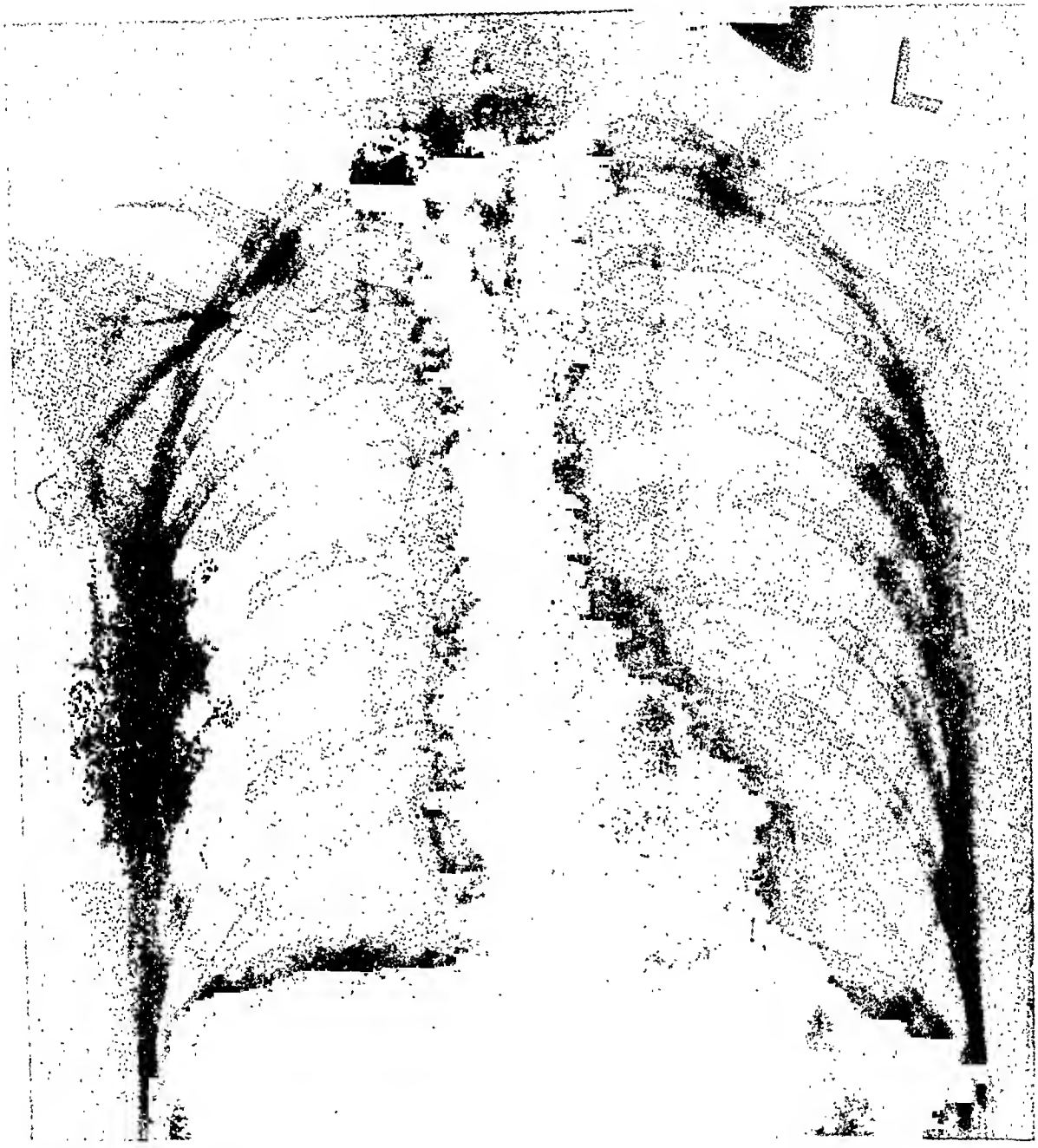


FIG. 6.—*Barium injection: Radiogram (P.-A.) at an early stage of injection.* The injection canula is seen in the left common carotid artery. The intercostals are commencing to fill by their anastomotic channels. The coarctation is shown to the left of the superior mediastinal shadow; the upper prominence is formed by the tortuous origin of the left subclavian (Fig. 5) and the lower prominence by the blind end of the descending aorta. Between this and the ascending aorta there is a narrow gap.

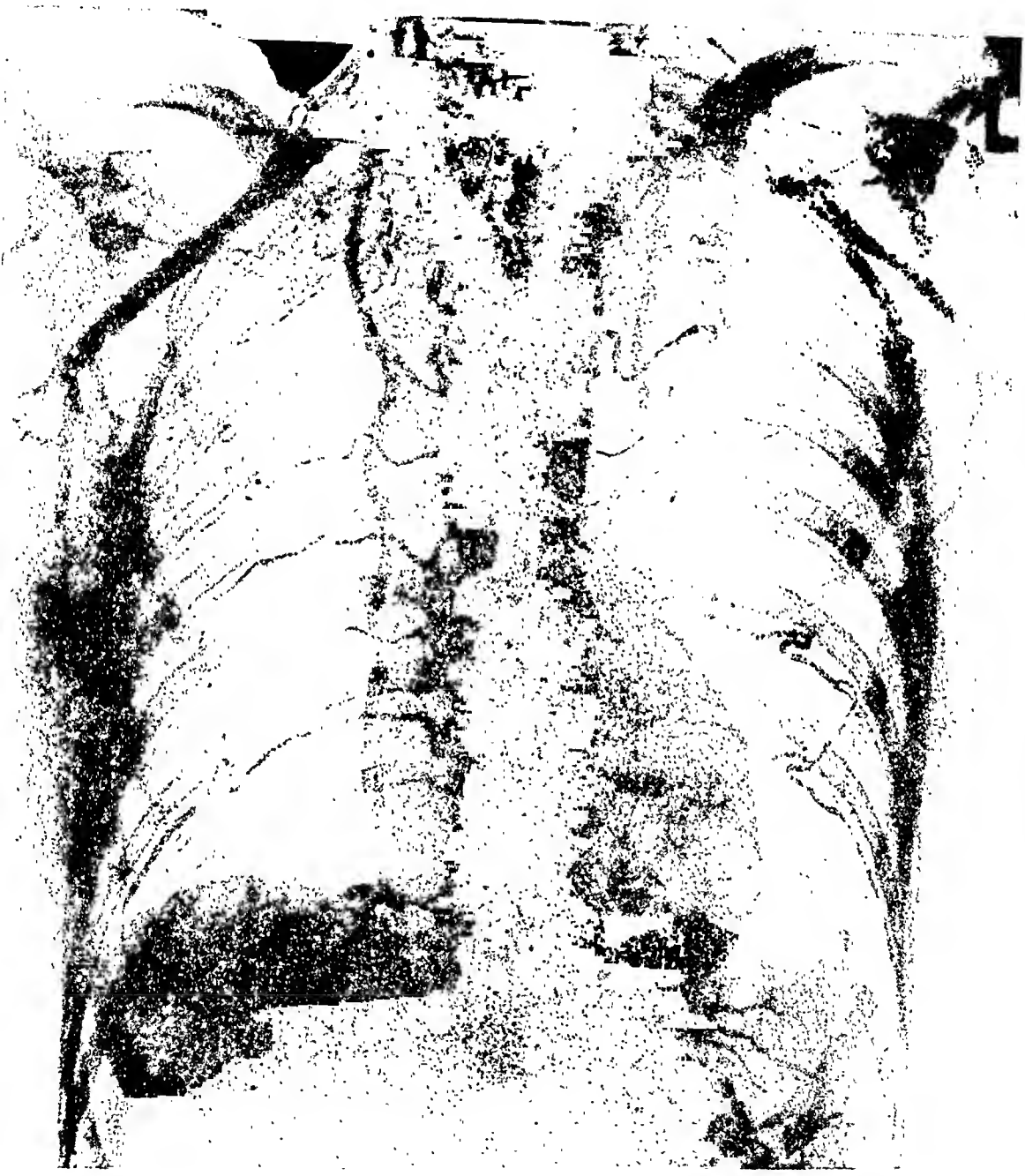


FIG. 7.—*Barium injection: Radiogram (P.-A.) at the end of injection.* The arteries shown on this radiogram are named in Fig. 8. The intercostal arteries have filled and are very tortuous. The notching of the ribs by the arterial loops is obvious. The internal mammary arteries are enlarged and the extensive diaphragmatic anastomosis formed by their musculophrenic branches and the phrenic branches of the aorta is well seen on the left side. The tortuous enlarged subscapular artery is visible on the right border of the chest; its dorsalis scapulæ branch encircles the neck of the scapula. Just medial to its origin is the long thoracic artery. The aortic intercostals supplying the fourth and fifth spaces are much enlarged near their origin from the aorta. This appearance is not a filling artefact, for all the barium was injected above the coarctation. The intercostals, therefore, filled by their collateral channels from the scapular network and the superior intercostal, and the distension near the descending aorta could not have been due to forcing barium into them from the aorta distal to the coarctation.

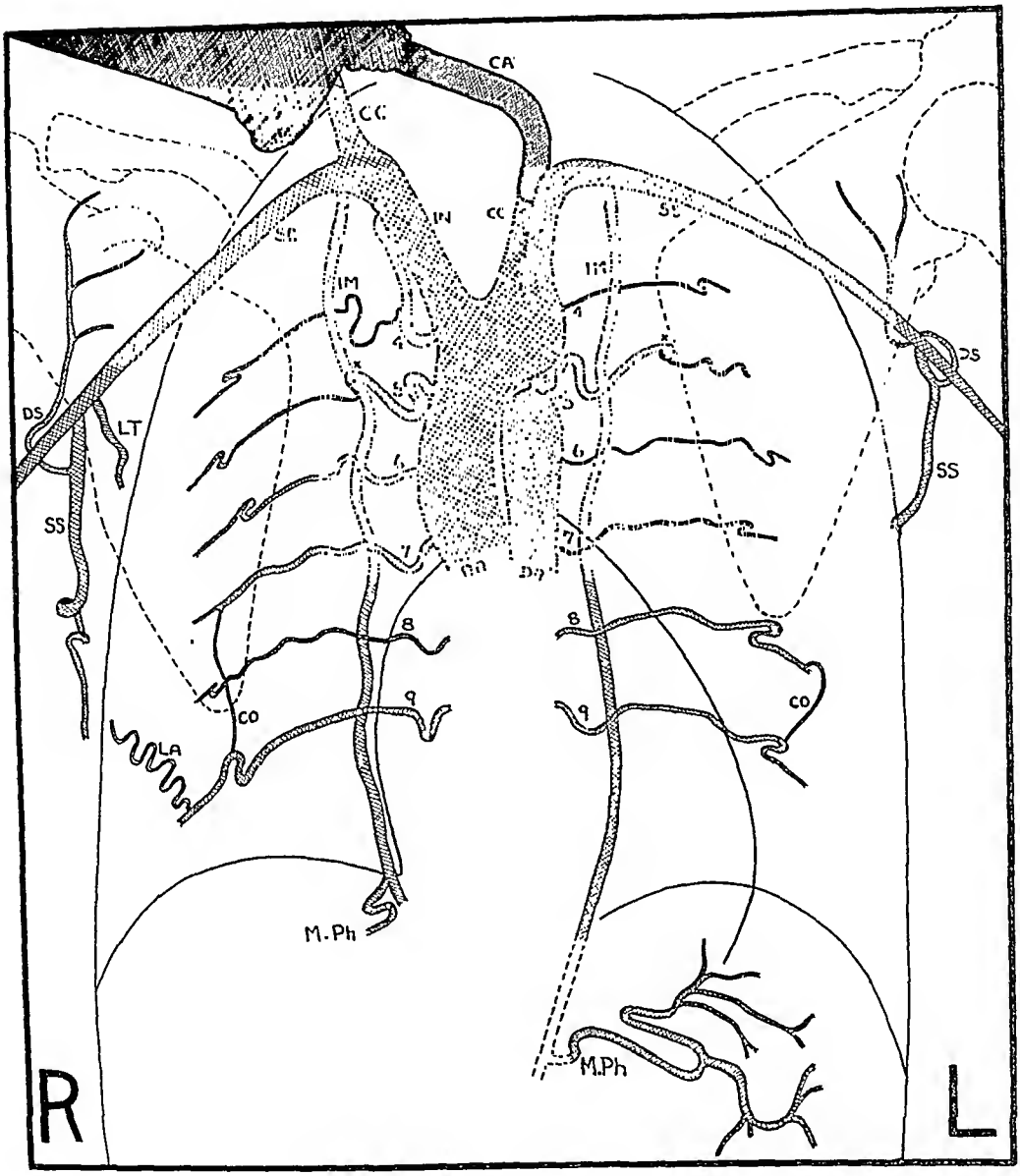


FIG. 8.—*Tracing from Fig. 7.*

CA—Injection Canula.

ARTERIES.

AA—Ascending aorta.

IN—Innominate.

SC—Subclavian.

LT—Long thoracic.

DS—Dorsalis scapulæ.

LA—Anastomosis of subscapular with aortic intercostals.

4, 5, 6, etc.—Aortic intercostals.

DA—Descending aorta.

CC—Common carotid.

IM—Internal mammary.

SS—Subscapular.

M.Ph.—Musculo-phrenic forming diaphragmatic anastomoses.

CO—Communicating branches between intercostals.

XX—The points at which the second aortic intercostals (supplying the fifth spaces) notch the ribs.

FIG. 9.—*Barium injection: Radiogram in the left anterior (II) oblique position, at the end of injection.* The coarctation is clearly seen and is crossed by two tortuous and enlarged aortic intercostals passing almost vertically upwards to their anastomosis with the superior intercostal. The extensive diaphragmatic anastomosis is seen.

FIG. 10.—*Barium injection : Radiogram of the aorta in the left anterior (11) obliaue position.* The coarctation is shown and appears to be complete. The aortic valve and the sinuses of Valsalva are seen. The valve is obviously competent.

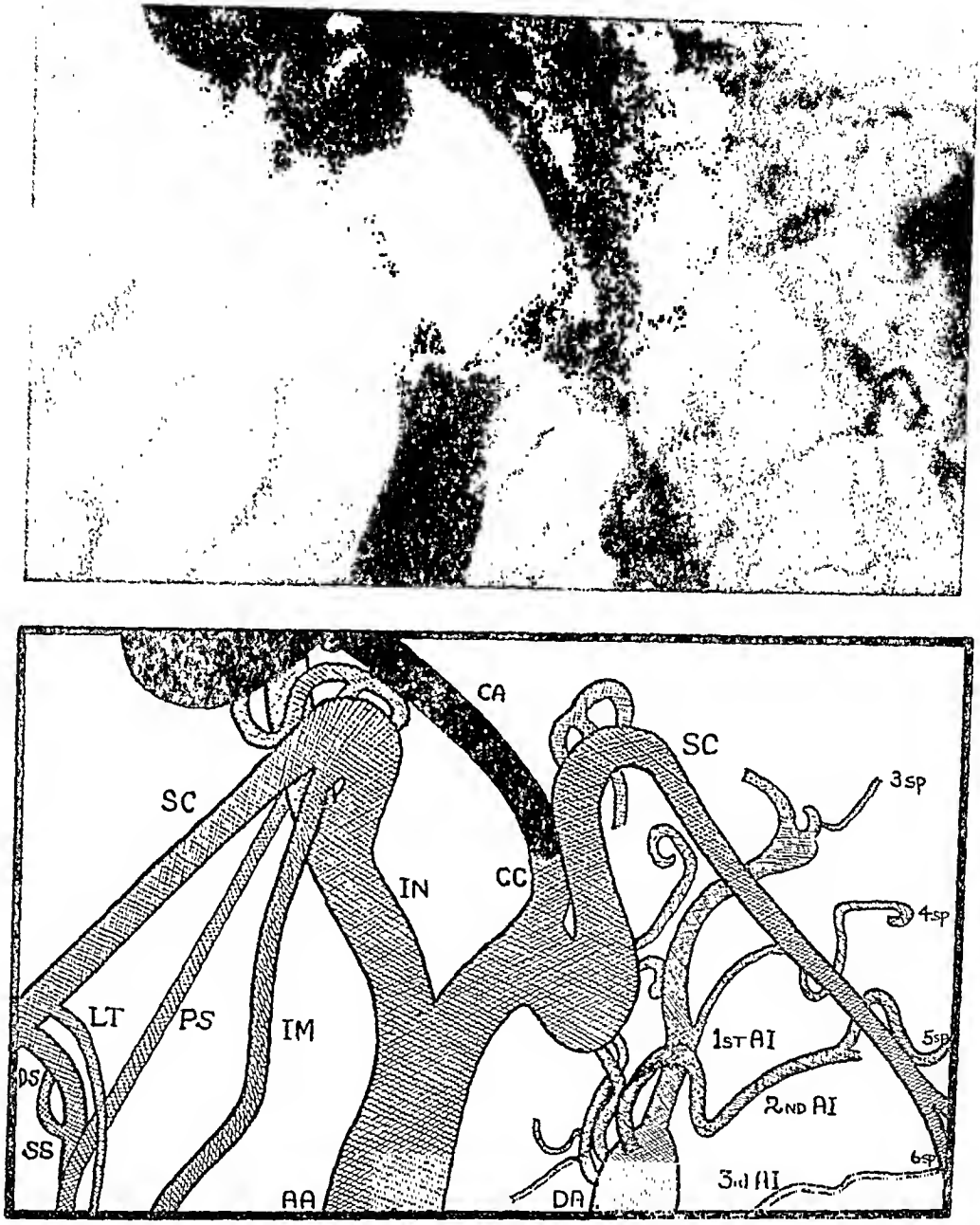


FIG. 11.—*Radiogram in a left oblique position, showing the coarctation.*

Key.—The arteries arising below the coarctation are represented in a darker shade.

CA—Injection Canula.

LT—Long thoracic. DS—Dorsalis scapulæ. IN—Innominate.
PS—Posterior scapular. SS—Subscapular. CC—Common carotid.
IM—Internal mammary. SC—Subclavian. AA—Ascending aorta. DA—Descending aorta.
1st AI, 2nd AI, etc.—first and second left aortic intercostals, etc.
3sp, 4sp, etc.—branches of left aortic intercostals to third and fourth spaces, etc.

The left subclavian forms a continuation of the aortic arch. The first left aortic intercostal (1st AI) runs almost vertically upwards, and gives off branches to the fourth and third intercostal spaces (4sp and 3sp); its main trunk anastomoses with the superior intercostal. The second and third left aortic intercostals (2nd AI, 3rd AI) are visible. The origins of the right aortic intercostals are hidden by the descending aorta (DA).

FIG. 12.—*Barium injection: Radiogram of the abdominal vessels.* The complete injection of the abdominal vessels is shown. As the barium was all injected above the coarctation these must have filled by the collateral channels. The well-known anastomosis between the superior and deep epigastric arteries was absent in this case.

Discussion

Clinically, the collateral circulation is revealed by palpable dilated arteries on the back or front of the chest, and by the late systolic murmur sometimes audible over these vessels; radiographically, its important manifestation is notching of the ribs by the enlarged and tortuous intercostal arteries. These features merit further consideration.

The Anastomotic Pattern

The blood has a choice of routes whereby to reach the aorta beyond the coarctation, and it would be interesting to know whether the circulatory efficiency in different cases is related to the anastomotic pattern.

In Table I we have enumerated, and in Fig. 13 we have endeavoured to depict diagrammatically, the various collateral channels which may be of importance.

TABLE I

Collateral Channels in Coarctation of the Aorta

1. The Scapular and Cervical Anastomoses:

The following arteries form a network around the scapula and in the cervical region:

(a) Suprascapular and transversalis colli (from thyroid axis).
(b) Posterior scapular and superficial cervical (from transversalis colli).
(c) Long thoracic and subscapular with its dorsalis scapulæ branch (from axillary artery).

From this network descending branches anastomose with the lateral and dorsal branches of the aortic intercostals.

2. The Internal Mammary Anastomoses:

(a) Superior epigastric → deep epigastric branch of external iliac.
(b) Musculo-phrenic → phrenic branches of thoracic and abdominal aorta.
(c) Mediastinal branches → mediastinal branches of aorta.
(d) Anterior intercostals → terminal branches of aortic intercostals.

3. The Intercostal Anastomoses:

(a) The terminal branches → the intercostal branches of the internal mammary.
(b) The lateral branches → the subscapular and long thoracic.
(c) The dorsal branches → the posterior scapular.
(d) The first and second intercostals (arising from the subclavian by the superior intercostal) → the upper aortic intercostals.
(e) Each intercostal → those above and below.

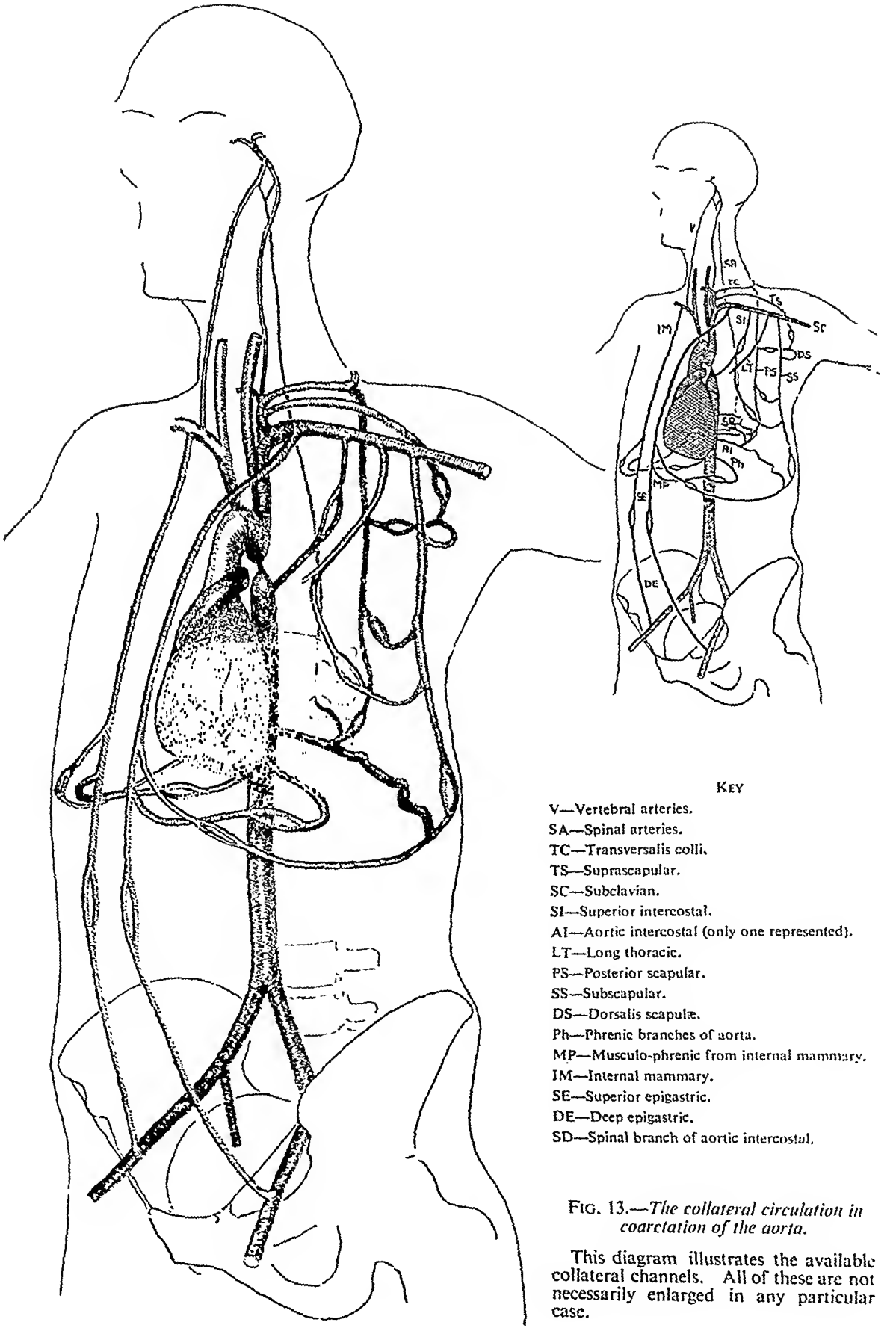
4. The Spinal Anastomoses:

The vertebral artery, arising from the first part of the subclavian, reinforces the spinal arteries in which the blood flows downwards to reach the spinal branches of the aortic intercostals. These pass through each intervertebral foramen. There are also branches from the inferior thyroid which pass through the intervertebral foramina in the neck to join the spinal arteries.

In our case the main anastomoses were :

(a) By the scapular and cervical branches of the subclavian and axillary arteries to the lateral and dorsal branches of the aortic intercostals, forming a network around the scapula and in the neck.

(b) By the musculo-phrenic branch of the internal mammary to the



KEY

V—Vertebral arteries.
SA—Spinal arteries.
TC—Transversalis colli.
TS—Suprascapular.
SC—Subclavian.
SI—Superior intercostal.
AI—Aortic intercostal (only one represented).
LT—Long thoracic.
PS—Posterior scapular.
SS—Subscapular.
DS—Dorsalis scapulæ.
Ph—Phrenic branches of aorta.
MP—Musculo-phrenic from internal mammary.
IM—Internal mammary.
SE—Superior epigastric.
DE—Deep epigastric.
SD—Spinal branch of aortic intercostal.

FIG. 13.—*The collateral circulation in coarctation of the aorta.*

This diagram illustrates the available collateral channels. All of these are not necessarily enlarged in any particular case.

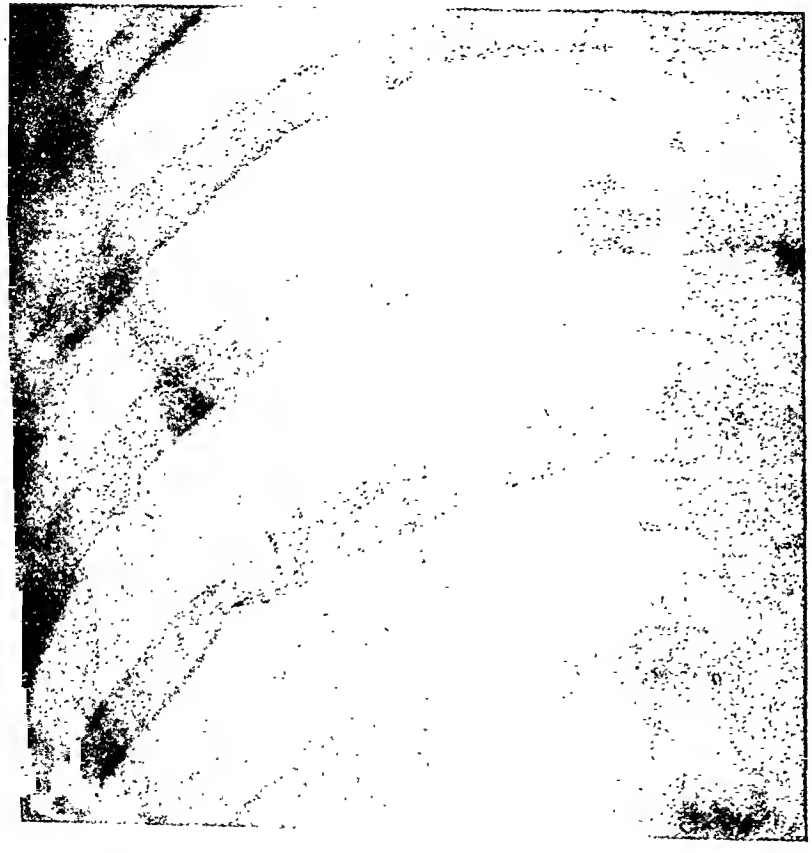


FIG. 14.

FIG. 15.

Rib notching. The conspicuous notch on the right ninth rib is shown before (Fig. 14) and after (Fig. 15) injection of the intercostal artery. The outer notch has a characteristic a symmetrical shape, with a gradual slope on one side and a steep slope on the other; the way in which the arterial loop produces a notch of this shape is seen. The inner notch does not show this characteristic shape. See text, p. 222.

inferior phrenic branches of the abdominal aorta and the smaller superior phrenic branches of the thoracic aorta, forming a network below and above the diaphragm.

(c) By the upper two intercostals, from the superior intercostal, to the upper aortic intercostals.

The importance of the anastomosis between the superior and deep epigastric has been stressed in most accounts, possibly because it is easily palpable. In our case (Fig. 12) it was insignificant. Likewise the anastomosis between the anterior intercostals (arising from the internal mammary) and the terminal branches of the aortic intercostals was poorly developed, the great enlargement of the internal mammary being due chiefly to the extensive diaphragmatic anastomosis. Unfortunately, at the time these observations were made we did not realize the importance of the spinal anastomosis (Table I and Fig. 13), and consequently no attempt was made to study it.

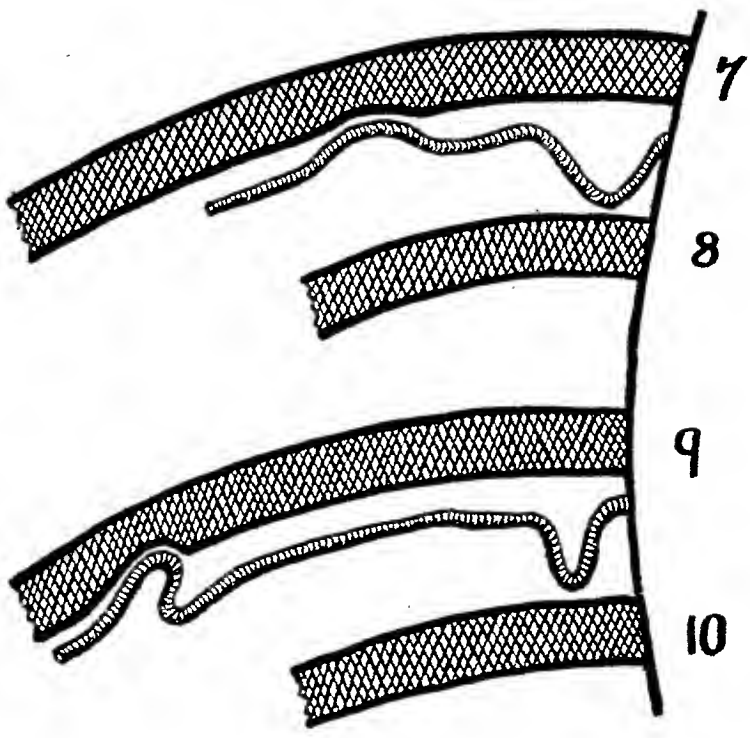


FIG. 16.—*The formation of rib notches.* The two intercostal arteries illustrated are drawn from the seventh and ninth right intercostals shown on Fig. 7. The seventh intercostal forms a smooth, shallow, symmetrical erosion on the seventh rib, but the greater tortuosity of the ninth intercostal produces a notch of characteristic shape. This type of notch can be seen on several ribs in Fig. 7. The drawing also illustrates how the intercostals may be very tortuous near the necks of the ribs without notching them, since here the arteries are some distance from the lower margins of the ribs (see text, p. 222).

Rib Notching

(a) *The Formation of Notches.* It was suggested by Arendt (quoted by Wolke, 1937) that rib notches in coarctation were of two types: shallow notches due to the tortuosity of the arteries, and deeper, punched-out notches due to small aneurysms on the intercostal arteries. Wolke (1937) studied radiographically a single aortic intercostal injected with iodized oil and arrived at the conclusion that it was unnecessary to invoke aneurysm formation, as the tortuosity of the artery was sufficient to account for both types of notch.

Our observations confirm those of Wolke. Fig. 14 and 15 (p. 220) illustrate how an arterial loop may form a notch, and in Fig. 16 we have represented diagrammatically the formation of shallow and deep notches by the different degrees of tortuosity of the intercostal artery. From Fig. 14 and 15 it is clear that the deep notches have a very characteristic shape; they are asymmetrical, with a gradual slope on one side and a steep slope on the other. This shape is determined by the form of the arterial loop, which is remarkably constant; several such loops are visible in Fig. 7.

(b) *The Distribution of Notching.* The distribution of notching is interesting. The notches in the present case were on the fourth, fifth, sixth, seventh, and ninth ribs on the right and on the fourth, fifth, sixth, eighth, and ninth ribs on the left (Fig. 17). We have studied the distribution of the notching in the radiograms of the other twelve cases in our series. This is tabulated in Table II, (p. 226) illustrated in Fig. 18 (p. 224), and represented graphically in Fig. 19.

The data enumerated indicate that notching is commonly confined to the ribs between the third and the ninth. It is absent in the first two ribs because the upper two intercostal arteries arise from the subclavian by the superior intercostal ; unlike the other intercostals, they arise above the coarctation. Near their origin they give off large branches, which anastomose with the upper aortic intercostals; after this they play no further part in the collateral circulation and do not become tortuous.

The aortic intercostals supply the intercostal spaces from the third downwards. They become tortuous because a large amount of blood enters their dorsal and lateral branches from the scapular network. The number of aortic intercostals that enlarge depends upon the site of termination of the subscapular, posterior scapular, and other descending branches of the scapular network. The shorter collateral channels to the upper aortic intercostals naturally enlarge first, and this is probably the reason why notching seldom extends below the ninth rib.

The notches are always confined to the posterior and lateral portions of the ribs; the anterior portions are never involved. This is probably due to the fact that the main blood flow enters the intercostals by their lateral and dorsal branches, whereas the anterior intercostals, arising from the internal mammary, are comparatively unimportant.

Sometimes, as in the present case, a double series of notches occurs (Fig. 17). When this is so, the inner notches are almost invariably confined to the third, fourth and fifth ribs (Table II and Fig. 18 and 19). The third, fourth, and fifth

intercostal spaces are the first to be supplied by the aortic intercostals. In the present case the first aortic intercostal supplied the third and fourth spaces; it was greatly enlarged, and its main trunk anastomosed with the superior intercostal (Fig. 11). The second aortic intercostal supplied the fifth space.

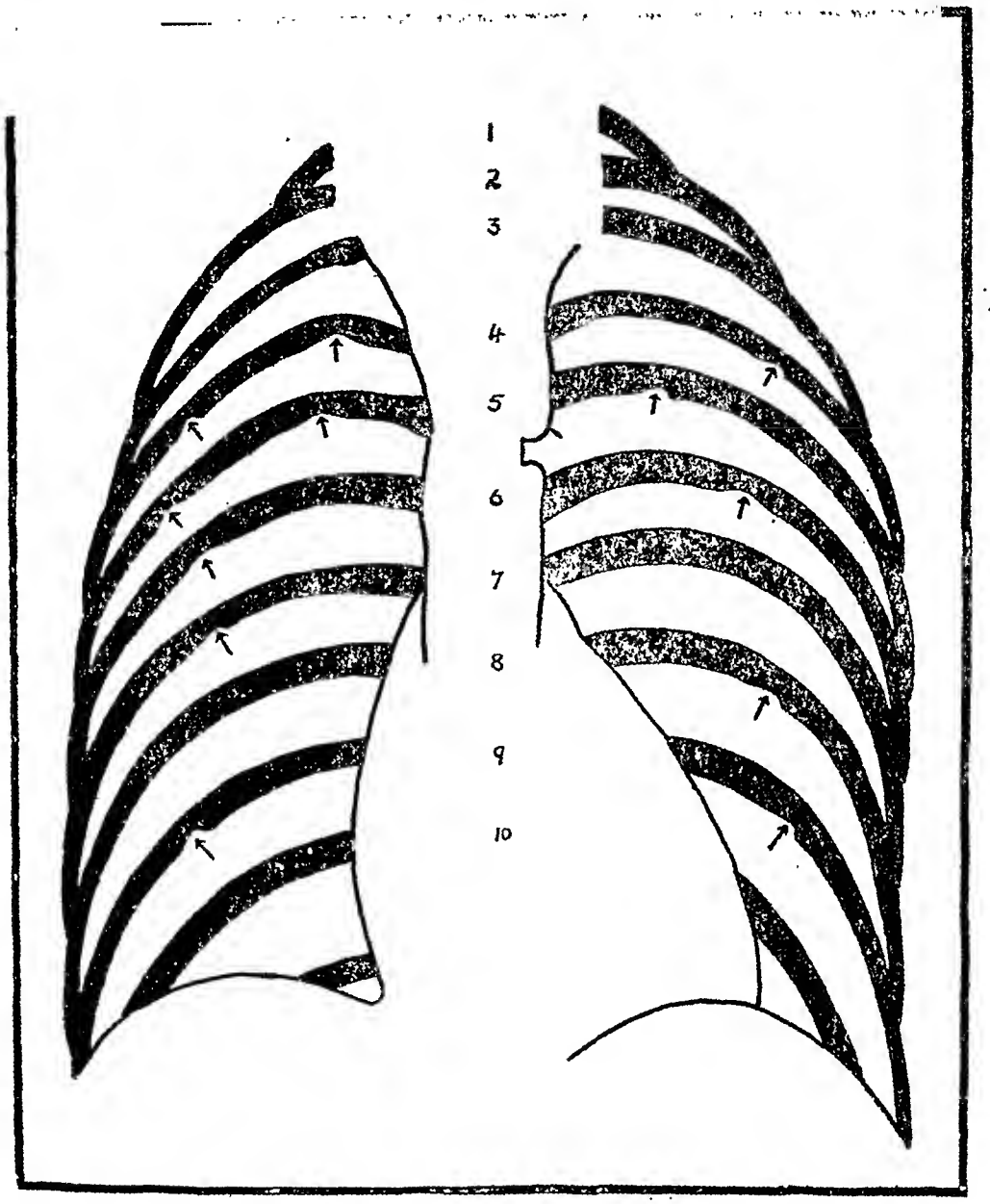


FIG. 17.—*The position of rib notches.* This diagram is taken from Fig. 6 and illustrates the position of the definite notches in this case.

It was also considerably enlarged, but on both sides it diminished suddenly in size about two inches from the aorta. This occurred because at this point the artery gave off a large branch, which turned upwards towards the superior intercostal. At its origin this branch notched the fifth rib on each side (Fig. 7 and 8); these notches are represented in Fig. 17 and are examples of the

inner group of notches depicted in Fig. 18. The anastomosis between the upper aortic intercostals and the superior intercostal therefore appears to be responsible for the production of the inner group of notches. This accounts

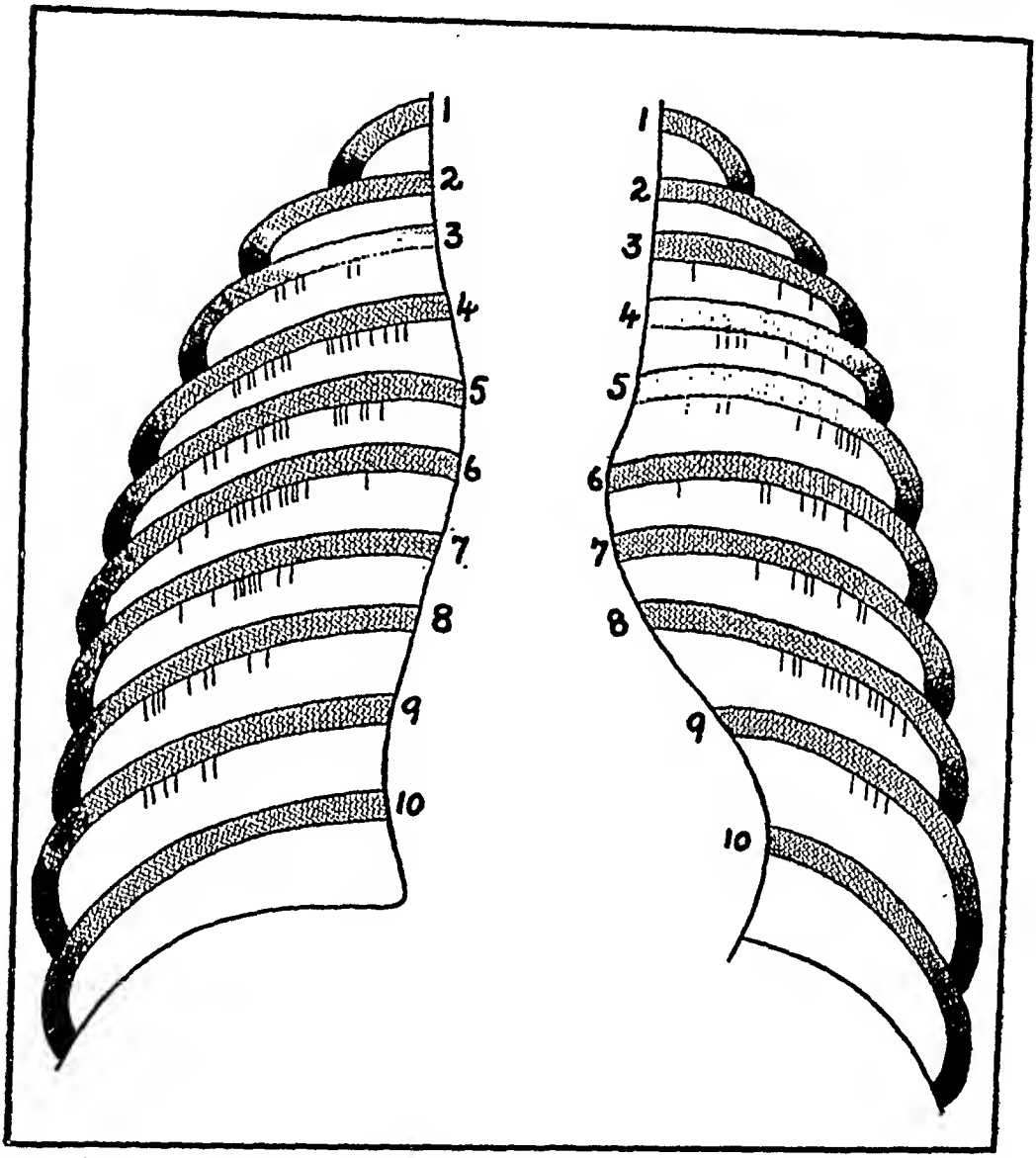


FIG. 18.—*The distribution of rib notches in thirteen cases of coarctation of the aorta.* The position of the definite notches seen in A.-P. radiograms of thirteen cases have been represented on a single diagram in order to show their positions on each rib and to indicate the ribs most frequently notched. The notches may be separated into an inner group on the third to the sixth ribs and an outer group on the third to the ninth ribs.

for the position of the notches near the spine and for the fact that they occur only on the third, fourth, and fifth ribs.

The outer group of notches is due to the anastomosis of the aortic intercostals with the descending branches of the scapular network and has a different distribution. These notches are situated more laterally, they extend as low as the ninth rib, and are most frequent from the fifth to the eighth ribs (Fig. 19).

The distribution of the notches in the present case is illustrated in Fig. 17 and is typical. It is striking that the outer notches tend to lie vertically under one another (Fig. 17) and in a fairly constant position (Fig. 18). Notching is due to tortuosity of the arteries, and tortuosity is most likely to occur midway between two fixed points on the artery. In searching for such fixed points one naturally thought of the nutrient branches of the ribs, but these are inconstant in position. The origins of the dorsal and lateral branches of the intercostals,

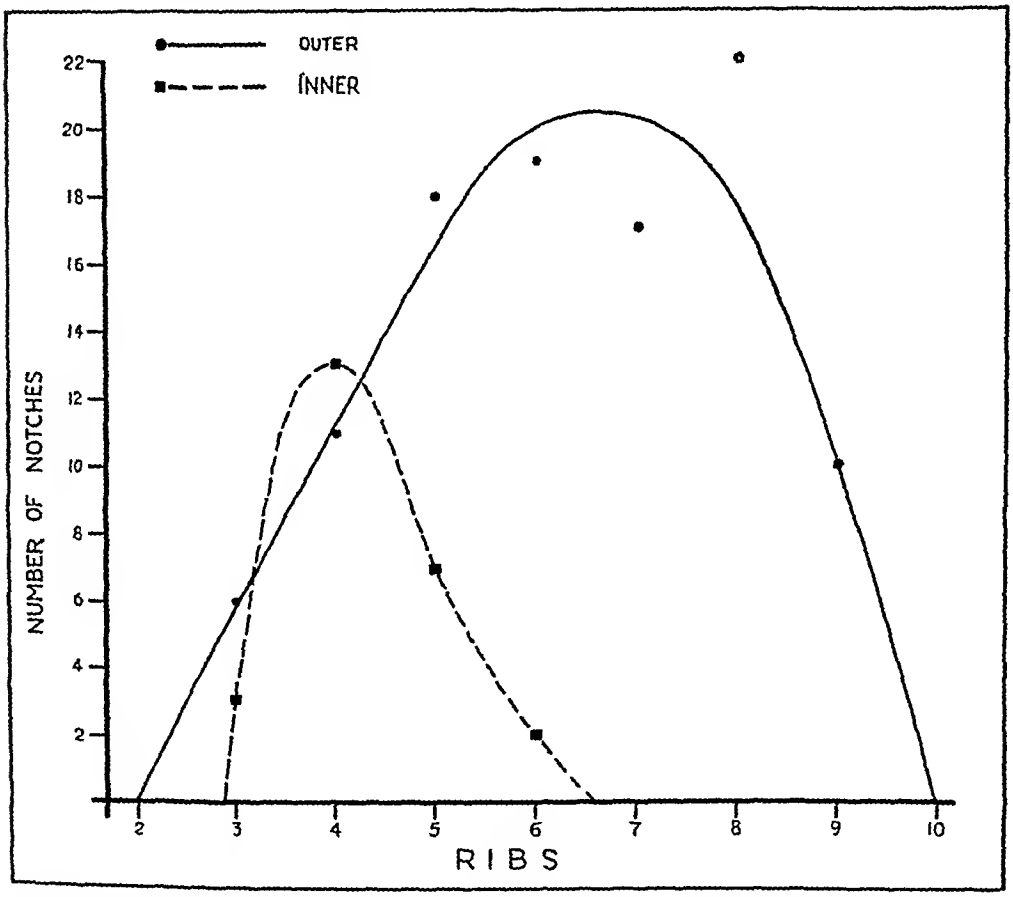


FIG. 19.—*Graph illustrating the distribution of rib notching in coarctation of the aorta.* The distribution of rib notching illustrated in Fig. 18 has been represented graphically. The curves illustrate how the outer notches occur most frequently on the fifth, sixth, seventh, and eighth ribs, whereas the inner notches are commonest on the fourth rib.

on the other hand, are fairly constant in position, and, because these branches pierce the fascial and muscular planes of the chest wall, they anchor the intercostal arteries at these points. The position of the outer notches supports the hypothesis that tortuosity first develops midway between these two points. The communications between the seventh intercostal and the loop on the ninth right intercostal and between the eighth left intercostal and the loop on the corresponding ninth intercostal (Fig. 7, 8, and 15) are interesting, for they may account for the position of some arterial loops.

Another fixed point is the origin of the intercostal from the aorta. Between this point and the origin of the dorsal branch considerable tortuosity may

develop (Fig. 7 and 8). This was illustrated diagrammatically in Fig. 16. It is, however, uncommon for notching to occur in this situation, for here the intercostal arteries are not in such close relation to the ribs.

TABLE II

DISTRIBUTION OF RIB NOTCHING IN THIRTEEN CASES OF COARCTATION OF THE AORTA

Rib	Right			Left			Total Outer	Total Inner	Complete Total
	Outer	Inner	Total	Outer	Inner	Total			
1	—	—	—	—	—	—	—	—	—
2	—	—	—	—	—	—	—	—	—
3	4	2	6	2	1	3	6	3	9
4	8	9	17	3	4	7	11	13	24
5	10	6	16	8	3	11	18	9	27
6	13	1	14	6	1	7	19	2	21
7	10	—	10	7	—	7	17	—	17
8	9	—	9	13	—	13	22	—	22
9	6	—	6	4	—	4	10	—	10
10	—	—	—	—	—	—	—	—	—
11	—	—	—	—	—	—	—	—	—
12	—	—	—	—	—	—	—	—	—
Totals	60	18	78	43	9	52	103	27	130

Rib notching may occur quite early in life. It was well developed in our youngest patient, a boy of 11, and Brown (1939) states that it has been reported at the age of 6.

Laubry (1937) has reported notching of the ribs in conditions other than coarctation of the aorta. He described six cases of aortic incompetence and of hypertension in which notches were seen. These differed from the notches in coarctation, for they occurred as a rule in elderly subjects, they were shallow, and limited to a few of the lower ribs, and were usually near the spine. They must be extremely uncommon, and their existence does little to diminish the diagnostic value of the discovery of rib notching in coarctation of the aorta.

Pain

Our patient's principal complaint was pain on exertion, in the scapular region; and pain was the presenting symptom in three other cases in our series. In one of these the patient had first noticed pain in the lower interscapular region at the age of 17. This persisted, and, at the age of 21, led him to consult an osteopath, who treated him unsuccessfully for eighteen months by manipulation of the spine. In the other two cases the pain was in the right arm and around the left costal margin respectively.

In two of the four cases reported by King (1926) pain was a prominent symptom. One of his patients, a man of 35, complained of pain on exertion in the left side of the chest; a year later a similar pain developed in the right chest. In King's other patient, a man of 58, the pain was in the left supraclavicular fossa and left shoulder, and corresponded in position to an area of arterial pulsation. It occurred only on exertion and for a considerable period it was the only symptom.

These cases illustrate that pain may occur in several situations, but it is always confined to the upper part of the body. It is in this area that the collateral circulation is developed, and in one of King's cases the pain was localized to an area of arterial pulsation.

Enlarged collateral channels might produce pain in several ways. When the pain is in the back it is possible that it may be due to erosion of the ribs, but the frequency with which rib notching occurs without pain throws doubt on this explanation. Pain in the arm, or around the costal margin, is more suggestive of root or nerve pressure, which might be due to the enlarged anastomotic artery passing through the intervertebral foramen (Fig. 13). The relation of the pain to exertion could be explained by the increased blood flow through the tortuous and pulsating collateral channels, and the differing sites of pain may be related to differences in the anastomotic pattern.

These various considerations suggest that the enlarged pulsating vessels of the collateral circulation are instrumental in the production of this symptom, and that in some instances the pain may be due to nerve pressure or to the erosion of bone.

SUMMARY

1. The post-mortem findings in a patient with coarctation of the aorta who died from subarachnoid hæmorrhage due to a ruptured cerebral aneurysm have been described.

2. As the coarctation had been diagnosed and the condition fully investigated two years previously, it was possible to compare the clinical and post-mortem findings.

3. Prior to autopsy the cadaver was injected with barium paste and the arterial anastomoses studied radiographically.

4. The anatomy of the collateral circulation has been described. The factors that determine the distribution of rib notching and some possible causes of pain in this condition have been discussed.

We are grateful to Sir John Stopford for his help and interest in this work; to Mr. F. S. A. Doran, who kindly drew for us Fig. 13; to our colleague, Dr. E. Duff Gray, for the facilities afforded to us in his department, and to Dr. S. Nowell for his valuable help in the radiography of the cadaver.

REFERENCES

Brown, J. W. (1939). *Congenital Heart Disease.* London, pp. 56 and 61.
Ernstone, A. C. and Robins, J. A. (1931). *Amer. J. Roentgen*, **25**, 243.
King, J. T. (1926). *Arch. intern. Med.*, **38**, 69.
Laubry, C. and Balsac, R. H. de (1937). *Arch. Mal. Cœur*, **30**, 394.
Wolke, K. (1937). *Acta Radiol.*, **18**, 319.

CHANGES IN RENAL FUNCTION AND PERSISTENCE OF THE MURMUR AFTER LIGATURE OF A PATENT DUCTUS ARTERIOSUS

BY

GEOFFREY BOURNE

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When first seen the patient here referred to was suffering from infection of a patent ductus arteriosus by *Streptococcus viridans*. Ligature of the ductus and treatment by sulphapyridine effected a cure. Full clinical and operative details are described, together with a second case of patent ductus arteriosus infected by *B. influenzæ* and cured by ligation and chemotherapy, in a paper by Bourne, Keele, and Tubbs (1941).

The reason for the present publication is the existence of the following two points of interest, additional to the fact of cure, points which seem to deserve separate and full description :

(I) As a result of obliteration of the ductus there resulted a temporary but striking and prolonged impairment of renal function, associated with a marked increase of the diastolic blood pressure ;

(II) In spite of obliteration of the ductus the typical murmur persisted for some months.

The patient, a girl of 19, had been in good health until four months previous to her admission to St. Bartholomew's Hospital. She had suffered during this time from headache, lassitude, and undue sweating at night. Fever was present throughout this period. No peripheral or pulmonary embolic symptoms were reported or found. The heart was enlarged, especially to the left. The typical systolic thrill and murmur of patent ductus arteriosus were present. The blood pressure was 132/40. The pulmonary conus was seen radiographically to be enlarged. Blood culture proved on several occasions the presence of *Streptococcus viridans*. The growth became progressively less profuse with sulphapyridine therapy, and before operation the blood was sterile.

Since the ligation of the ductus, and for a period of nine months, she has remained perfectly well.

The following sentences are quoted from Mr. Tubbs' account of the surgical procedure, with slight abbreviation and modification. The ductus arteriosus was approached through the left pleural cavity, which was opened through the second left intercostal space, the skin incision extending from the mid-line in front to the anterior axillary line. The second and third costal cartilages were

divided close to the sternum, and excellent exposure was obtained by separating the ribs with a " rib-spreader ". The internal mammary vessels were divided between ligatures so that full use of the medial end of the incision might be obtained. The mediastinal pleura was incised parallel and posterior to the phrenic nerve, which was then retracted anteriorly. No difficulty was experienced in identifying the patent ductus. The cellular tissue under the arch of the aorta was gently swept from the anterior surface of the ductus with a pledget of gauze held in a long hæmostatic clamp. Keeping immediately against the wall of the ductus, the adjacent tissues were readily separated by blunt dissection, except from the postero-medial surface, where a plane of cleavage was found by tactile means and without visualization. This was done by insinuating the left index finger into the cleft between the aortic arch and the bifurcation of the pulmonary artery, anterior to the ductus. None but a trivial amount of hæmorrhage was encountered. The ductus was three-quarters of an inch in length and rather more then half an inch in diameter. It was obliterated by two doubled No. 5 tubular silk ligatures.

Renal Functions and Blood Pressure Changes

Previous to operation the average blood pressure reading was 130/40, and the urine, which contained no albumin or cells or casts, was sterile on culture. After the operation, and on the same day, the systolic blood pressure fell to 112, but in five hours rose to 130, the corresponding diastolic figures being 84 and 94. On the following day the figures were at first 136/116, and later 116/100. On the second and third days there was little change, but on the fourth day after operation the figures were 154/122 and 150/120. From this point the pressures slowly fell, reaction of 140/105 on the eleventh day. The systolic pressure then became reduced during the next week to between 130 and 140, where it remained, but the diastolic continued in the neighbourhood of 94, and not until six weeks after operation did it fall to the final permanent figure of 74 to 78.

During the whole of this post-operative phase no abnormal cells, no casts, and no albumin were found in the urine, but there was a gross diminution in renal efficiency. Eight days following operation the urea content of the blood was 62 mg. per 100 c.c., and fifteen days afterwards this had increased to 72 mg. per 100 c.c. On this day the standard urea clearance was 21·9 c.c., or 29·2 per cent of the average normal for the first hour, and 15·2 c.c., or 28 per cent, for the second hour. No urinary abnormality was found even at this stage. The urea clearance figures then slowly increased, so that on the twenty-third day after operation the figures were 53·5 per cent of the average normal for the first hour and 40·8 per cent for the second.

Two months later the respective figures were 66·6 per cent and 60·3 per cent. This renal failure was closely parallel in degree with the increase and subsequent return to normal of the diastolic blood pressure, and it had the characteristics of pure glomerular failure.

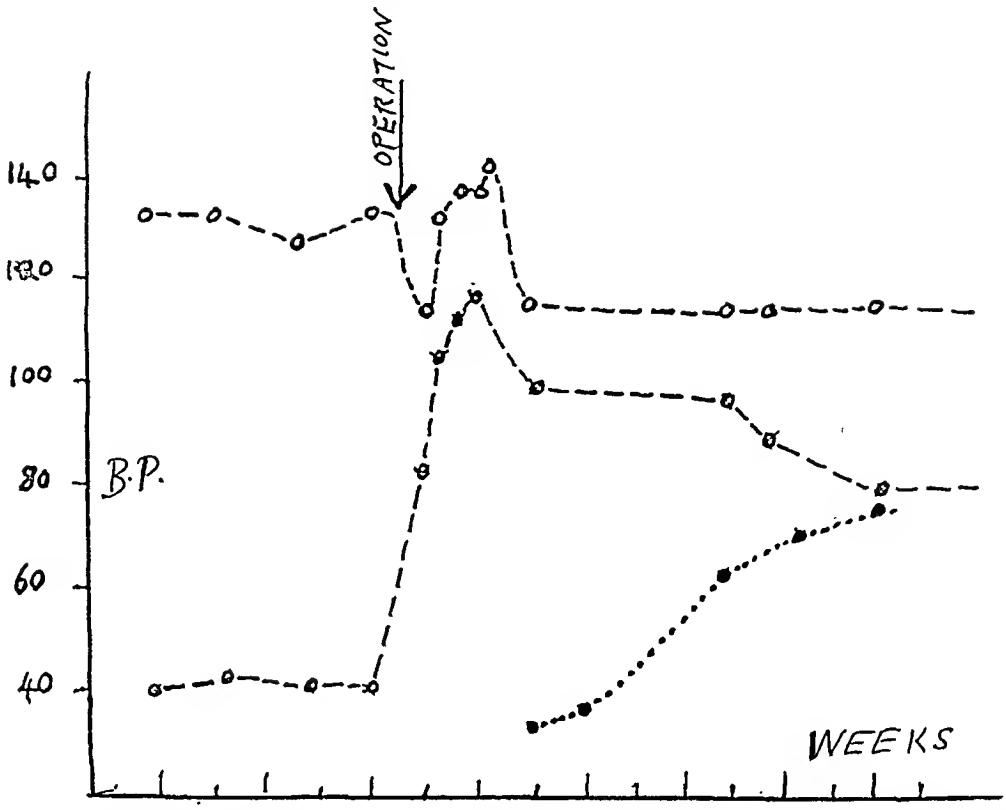

FIG. 1.—Changes in the blood pressure and renal function after ligation of a patent ductus arteriosus.

Divided lines : blood pressure, systolic and diastolic.
Dotted line : renal function, urea clearance, percentage of average normal.

The following hypothesis is offered to explain why the blood pressure and renal changes may have occurred.

Before operation the state of the cardiovascular system was as follows : The left ventricle was hypertrophied. The output per beat from this chamber was greater than normal. The total blood volume was larger than normal (Gross, 1939). The pulse curve was that of aortic incompetence, in which the peripheral arterioles were in a condition of more or less permanent partial relaxation. This cardiovascular state was normal for the patient, having been present for the whole of her nineteen years of life.

After operation the volume of the blood would have adjusted itself within a few days, and this can hardly be considered as a factor of significance. The left ventricular hypertrophy would remain for a number of weeks but might then disappear ; for when hypertrophy of the heart is produced in rabbits by experimental arterio-venous aneurysm it has been observed to disappear when the leak is closed again (personal communication, Dr. A. N. Drury). This has also been observed clinically in cases of arterio-venous aneurysm (Hitzig and Master, 1935). But during these weeks the ventricular output per beat might be expected to be increased above normal. This alone, however, could hardly be responsible for the renal and blood pressure changes.

It would seem that attention should therefore be directed to the state of

the peripheral arterioles. For the whole of the patient's life the nervous tone of the peripheral vessels had been adjusted for the arterial leak from the patent ductus ; and also stabilized as regards their neuro-muscular mechanism to react to the type of pulse curve found characteristically in aortic regurgitation. The vessel would thus have been in that state of permanent partial dilatation associated with a lowered diastolic blood pressure.

It is suggested that the effect of the increased output per beat upon this hitherto constantly relaxed vascular bed could produce a reflex over-reaction. This abnormally hypertonic state of the arterioles might be expected to continue until the vasomotor nervous system had readjusted itself to the new conditions, or until the hypertrophy of the left ventricle had become sufficiently resolved. The period of readjustment might persist for some weeks.

If this vascular spasm involved the glomerular as well as the systemic arterioles, a single explanation is available for the abnormally high diastolic pressure following operation, for the coexisting diminution in renal function, and for the fact that the urine at no time showed any cells, casts, or albumin.

It may be objected that the renal changes had no association with the tying of the ductus and the subsequent blood pressure variations but were the direct result of the infection ; and that when the infection was cured they naturally disappeared. In answer to this are the facts that although the blood urea was at one time 72 mg. per 100 c.c., at no time were red blood cells, casts, or albumin found in the urine, as is usually the case when kidney damage during endocarditis or septicæmia is extensive ; and no embolic signs were present elsewhere. Nor would recovery in such a case have been complete in so short a period. Finally, the relation between the renal and blood pressure changes is obviously a close one.

After ligature of the ductus in Case I (Bourne *et al.*, 1941) the diastolic pressure rose from 60 to 120, but later fell to the region of 80.

Similar elevation of diastolic pressure is characteristic of closure of arterio-venous aneurysms, both in man and in experimental animals, as Holman (1940) has pointed out in a full review of the subject.

Persistence of the Murmur

The murmur of patent ductus arteriosus is typically one that fills systole and is carried on into diastole. During this period the pressure in the aorta is at first systolic, and then, in proportion to the size of the arterial leak, it falls to a lower diastolic level than normal. The murmur is loudest at those periods of the cardiac cycle when the flow of blood from aorta to pulmonary artery is most rapid. This provides the classical explanation that the murmur is directly caused by this flow. In the case here described the murmur before operation was classical, and the aortic leak was large, but after ligature of the ductus the murmur persisted, although the leak was stopped. The blood pressure was completely changed by the operation, the figures before operation being 132/40, and after operation 136/116 at first and 130/80 finally. Two doubled tubular silk ligatures were used, and there is no reason to doubt that

they were effective. The persistence of the murmur was verified by four independent observers. It remained definite for three months, and six months later was far less loud, and its diastolic part is now (after nine months) nearly inaudible. Touroff (1940) noticed the same persistence of the murmur in two of his cases after ligature, but the length of its duration was unstated. In one of his cases the ductus was cut between two ligatures, thus disposing of a possible criticism suggesting that the ligation had been imperfect. It is clear that in all these cases the classical murmur was not caused in the manner usually suspected. It is therefore possible that it is never so caused ; its mode of production must therefore remain a matter for conjecture. Ligature of the patent ductus did, however, result in disappearance of the murmur in our Case 1 (Bourne *et al.*, 1941). Moreover Gross (1939), after the ligature of four non-infected cases, noted persistence of the double murmur, but with diminished loudness, in two cases, persistence of a soft systolic murmur in one case, and disappearance of the murmur in one case. At operation a faint systolic thrill could be palpated in the writer's case in the pulmonary conus after applying the first ligature, but after the second this was abolished.

Summary

A case of patent ductus arteriosus is described, in which ligature of the ductus

(1) caused a marked increase in the diastolic pressure, associated with great impairment of renal function, and

(2) did not result in disappearance of the classical murmur.

The hitherto undescribed changes in renal function and the persistence of the murmur, after ligature, are reported so that in future cases these points may be further investigated. Careful renal function studies should be done before as well as after operation in such cases.

References

Bourne, G., Keele, K. D., and Tubbs, O. S. (1941). *Lancet* (2,444).
Gross, R. E. (1939). *Ann. Surg.* **110**, 321.
Harrison, T. R., Dock, W., and Holman, E. (1924). *Heart*, **11**, 337.
Hitzig, W. M., and Master, A. M. (1935). *Mount Sinai Hosp.*, **1**, 269.
Holman, E. (1940). *Ann. Surg.* **112**, 840.
Touroff, A. S. W., and Vesell, H. (1940). *J. Amer. med. Ass.*, **115**, 1270.
Touroff, A. S. W. (1940). *J. thorac. Surg.* **10**, 59.

INVERSION OF THE T WAVES IN LEAD II CAUSED BY A VARIATION IN POSITION OF THE HEART

BY

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Only in late years has there begun to be adequate recognition of the wide variations of the normal human electrocardiogram. As has so often happened in medical science, diseased conditions and abnormal findings have attracted so much attention that a patient study of the normal subject and his physiological variations has been left far behind. This is particularly true in clinical electrocardiography where we still depend for our normal criteria on a relatively small number of records.

Leimdörfer (1935) reported the finding of a lowering, to an isoelectric or diphasic position, of the T waves of lead II in certain subjects on changing their body position from supine recumbency to standing.* This alteration of the T waves he ascribed to heart disease, not otherwise apparent; for this viewpoint, however, he had no adequate evidence. That same year, two of us (P.D.W. and A.G., 1935) published a paper in which we called attention to the occasional occurrence of inversion of the T wavés in lead II in persons without heart disease and in fact sometimes without any obvious disease at all. Several of these were young people of delicate build and subject to neurocirculatory asthenia. We stated that the reason for T wave inversion in these cases was unknown but that " the importance of this finding is that it points to the need of caution in the diagnosis of serious heart disease when inversion of the T wave in lead II is the only abnormal finding." In these cases the T waves in lead III were always more deeply inverted than those in lead II and " remained inverted in most instances (16 out of 23) after the T wave in lead II had ceased to be inverted."

As time went on after our own initial report we became cognizant of at least one of the factors which was responsible for the inversion of the T waves

* The records taken in the standing position were made with the breath held in full expiration with the express purpose of neutralizing the effect of the change in the position of the heart; it is our experience that with ordinary breathing in the upright position the T waves would often have been inverted in lead II, rather than merely isoelectric or diphasic, and that change in position of the heart with expiration alone may be insufficient to neutralize the effect of change in body position.

in leads II and III. We observed that the position of the body was of major importance and that a change from the upright position (seated) to recumbency (supine) often altered the T waves so that they became upright in lead II and less inverted, flat, or even upright in lead III. In 1938 we reported our findings in brief before the American Society for Clinical Investigation (by title and abstract) and before the New England Heart Association. We stated then that the electrocardiograms usually became normal with changes of position and after exercise. Electrocardiographic abnormalities reversible with changes in posture (sitting to supine) were often seen as transient phenomena associated with respiratory infections. The patients were mostly young adults of a nervous temperament and of asthenic habitus. Myocardial function, electrolyte balance, and heart position in relation to various body positions were studied and only the latter found to have a bearing on the electrocardiographic changes.

A variation similar to what we had encountered was reported by Åkesson (1936) and ascribed to orthostatic coronary insufficiency. He observed, among other things, that the greater the increase in pulse rate and the greater the fall in systolic blood pressure, when the subject stood erect, the greater was the decrease in the height of T in lead III. Åkesson, however, failed to distinguish between the T wave changes that occur immediately on assuming the upright position and those that occur as a result of the pooling of blood in the lower portions of the body. We too have observed significant changes in the T waves of the electrocardiogram associated with orthostatic hypotension and tachycardia, and believe they are due to alterations in sympathetic and vagal tonus and perhaps to a decrease in coronary blood flow. However, in the observations which we report below, this mechanism did not play a significant rôle.

Sigler (1938) reported the occasional occurrence of electrocardiographic alterations with change in body posture including in a few cases inversion of the T waves in lead II when the subject assumed the erect position, which he ascribed to " a change in contact of the adjacent conducting media with different portions of the heart on alteration of body posture, producing variation in conduction," and not to heart disease as Leimdörfer had done.

Two years ago an important observation came to our attention in helping to clear up the mystery of the inversion of the T waves in lead II in certain normal subjects. It was already evident that posture was important but just how a change in posture acted was not wholly clear. We now found that without a change in posture the typical changes in the T waves described above could sometimes be produced by deep inspiration and sometimes abolished by deep expiration. In other words, the height of the diaphragm is almost, if not quite, as important a factor as is body position, thus pointing to heart position in relation to other parts of the body as of prime significance. Rotation of the heart on its anteroposterior axis is probably a minor cause of the change, since often there is but little change in the angle of the electrical axis of the heart in the classical frontal plane of the body as measured from the QRS waves by the Einthoven formula or triangle. Rotation of the heart on its longitudinal axis is probably a more important factor in influencing the T waves with change in the heart's position. Nevertheless, it should be

recognized that the electrical axis of the T waves and of the QRS complexes are distinguishable and that an alteration or shift in the QRS axis need not be associated with a comparable shift in the T axis and vice versa.

Electrocardiograms illustrating the effect of posture and of respiration on the T waves in leads II and III were published by two of us (P.D.W. and A.G.) in our new book on electrocardiography (1941). Records of one case (Fig. 15 and 16 of the book) are reproduced herewith as Fig. 1. Other typical illus-

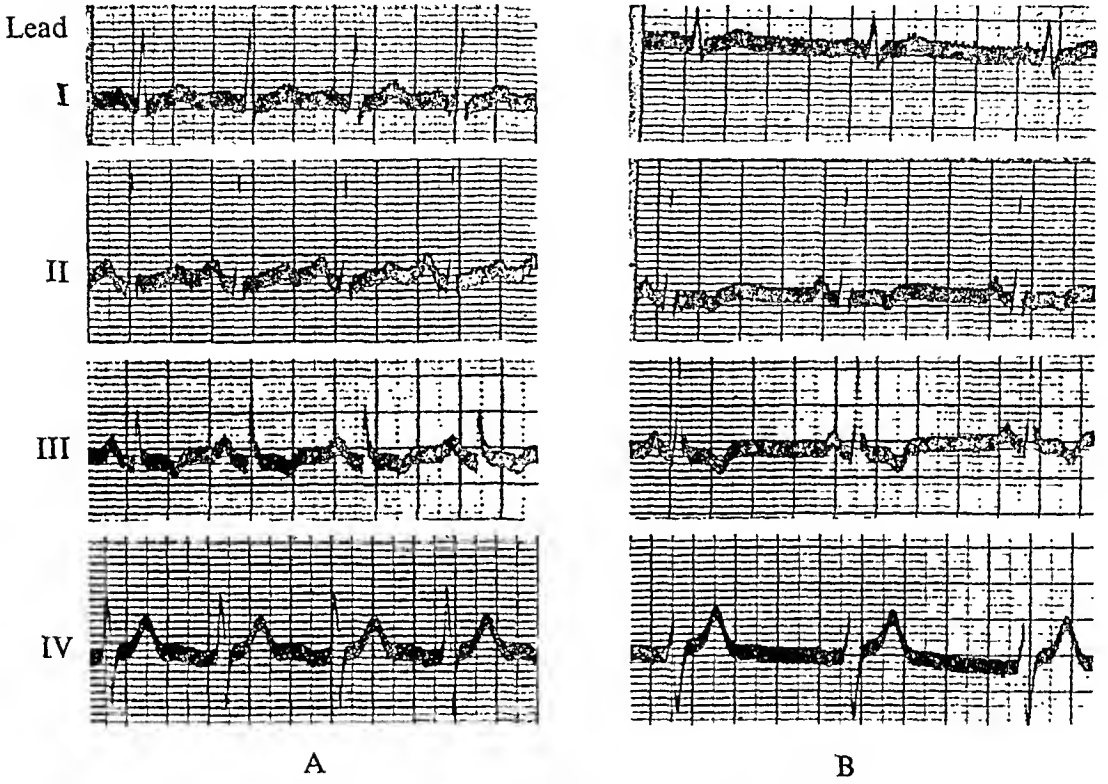

FIG. 1.—Electrocardiographic changes with respiration in a healthy young man of stocky build. (A) During quiet respiration. (B) In full inspiration.

Note that here there is a distinct shift in the angle of the electrical axis of the QRS waves to the right as well as the inversion of the T waves in lead II upon lowering the diaphragm and making the heart much more vertical in its position. There may or may not, however, be much of any change in the QRS waves with change in the T waves.

trations are shown in Fig. 2, 3, 4, and 5 of the present paper. It should be noted that changes in the S–T junctions and segments and in the T waves in leads I and IV are relatively slight and unimportant in comparison with the changes in the late phases of the T waves in leads II and III.

Recently Scherf and Weissberg (1941) have reviewed the subject and have arrived at the same conclusions as ourselves; they pointed out that the T waves in lead II may be simply lowered rather than inverted, and emphasized particularly the inversion of T in lead III and its change in 35 normal adults. They concluded that their " observations speak against the assumption that cardiac damage or anoxia of the heart muscle can be the factor responsible for the electrocardiographic alterations. They confirm the conception that the

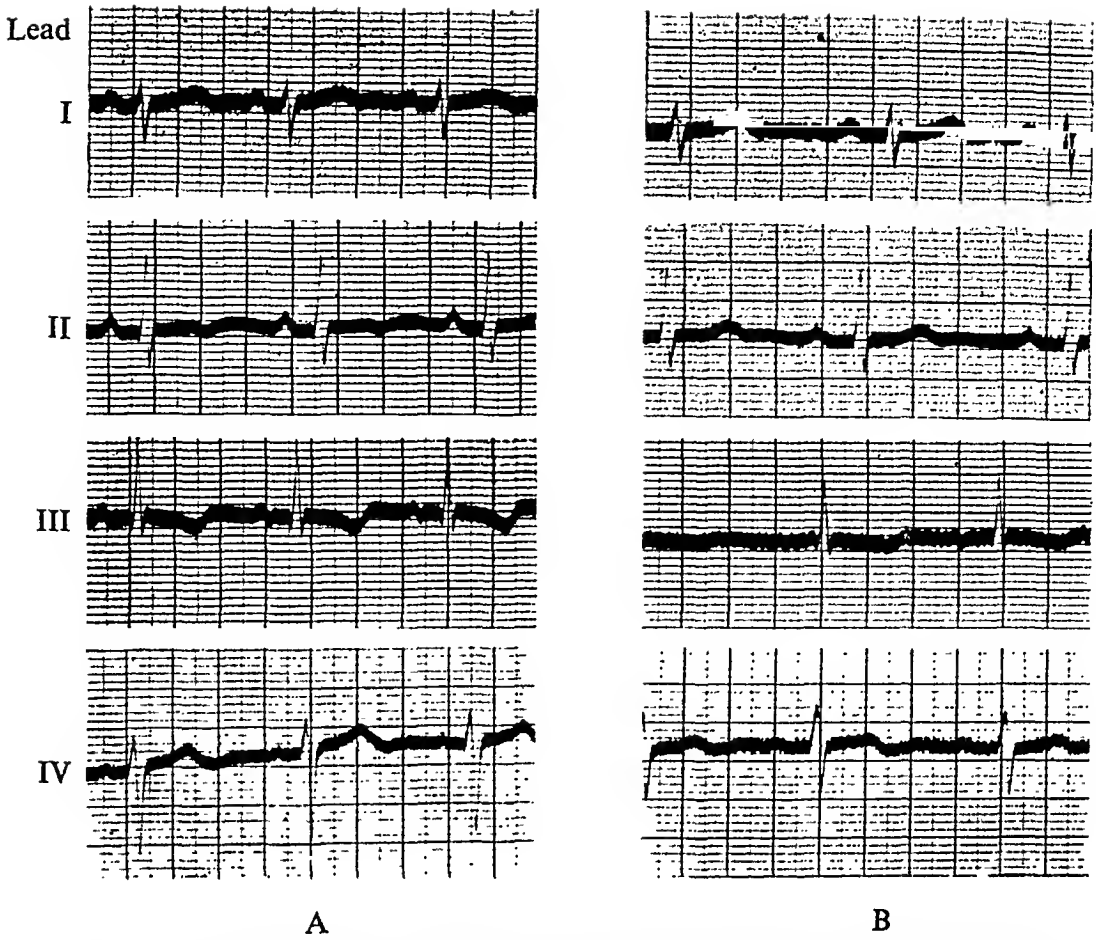

FIG. 2.—Electrocardiographic changes upon change in position from sitting to supine in the case of a young girl, 15 years old and of average build, with no clear evidence of heart disease but of nervous type. (A) Sitting. (B) Recumbent.

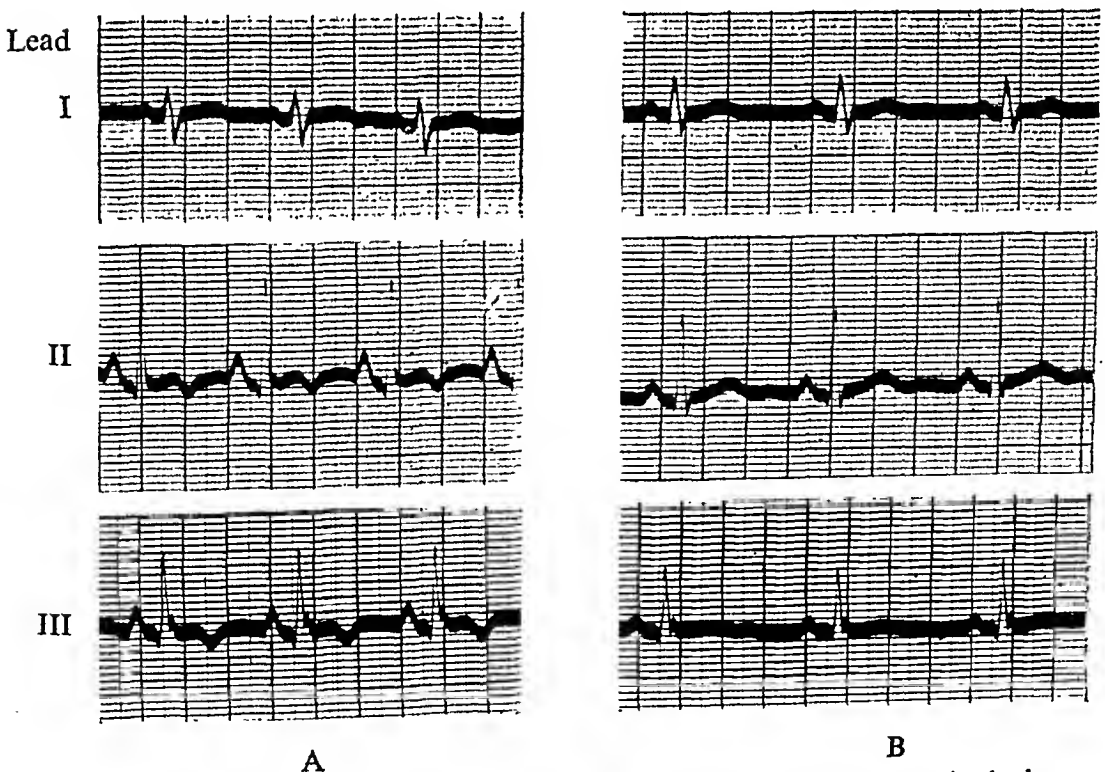

FIG. 3.—Electrocardiographic changes upon change in position from sitting to supine in the case of a young girl of 18, tall and thin, without evidence of heart disease.
(A) Sitting. (B) Recumbent.

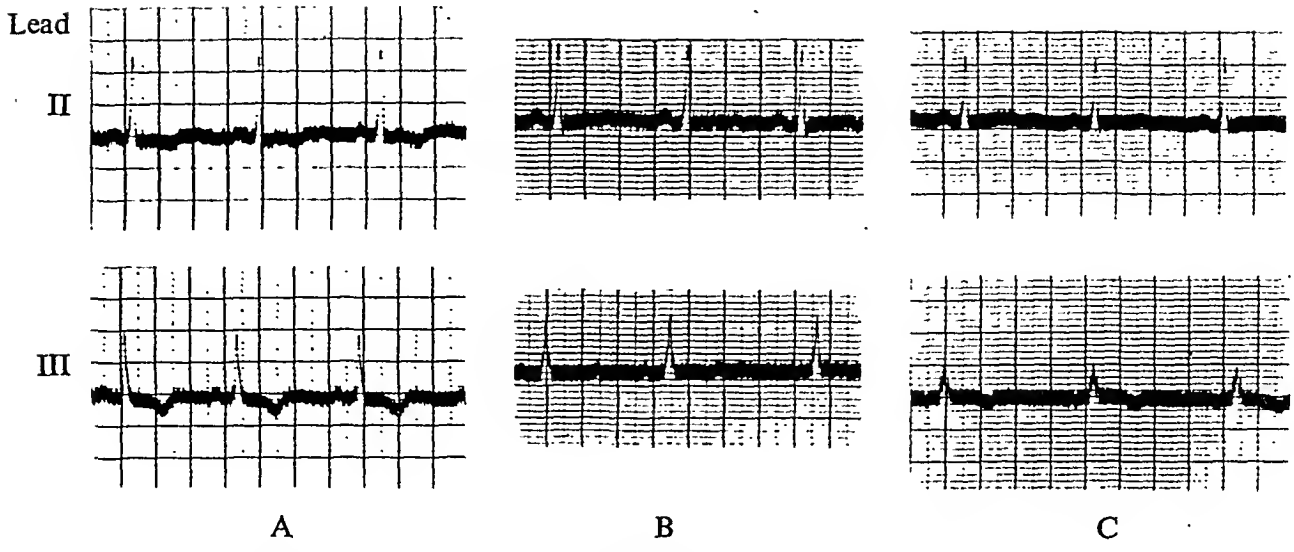

FIG. 4.—Electrocardiographic changes in leads II and III upon change of position from sitting to supine and upon full expiration, in the case of a boy of 15, tall and thin, with a normal heart, vertical in position.

(A) Sitting, during quiet respiration. (B) Recumbent. (C) Sitting, at end of full expiration.

inversion of the T wave is due to a change in posture and therefore a change in contact between the heart and the neighbouring tissues."

DISCUSSION

Lowering, flattening, notching, and inversion of the T waves in lead II are the result of a variety of causes, mostly diseases involving the heart itself. The majority of these are well recognized, ranging from the common changes due to coronary heart disease to the rare findings in myxœdema. Pericarditis, acute and chronic, is an occasional but important cause, acting doubtless through the subjacent myocardial involvement. Myocarditis of rheumatic or other rarer nature can cause such T wave changes, as can also the toxic effects associated with severe infections, renal toxemias and drug action, particularly the well-known intoxication by digitalis. Pronounced enlargement and strain of the right ventricle, acute or chronic, as in the cor pulmonale or in marked mitral stenosis, may cause diphasic flattening or inversion of the T waves in lead II as well as of those in lead III.

The abnormal causes of the changes in T in lead II listed in the last paragraph have been recognized for the most part for years, but interestingly enough the normal or physiological factors responsible for very similar changes have only begun to receive recognition long overdue. Even as recently as 1935 Leimdörfer, as stated above, assumed that such changes without evidence of heart disease or intoxication must of necessity mean that heart disease, particularly coronary insufficiency, is none the less present. Now we are learning better.

There are several physiological causes for changes of T in lead II, but these have not yet been clearly separated by the few writers who have paid any attention to the subject, and in all probability two or more factors are not rarely superimposed. Autonomic nervous influences (preponderantly sympathetic effects) from any cause (exercise, fever, or excitement) with resulting sino-auricular tachycardia, and perhaps also even paroxymal auricular tachycardia, is frequently—in fact usually—attended by a lowering of the T waves in lead II, in contrast to the increase in the height of the T waves that occurs when the vagal action becomes preponderant as during the slowing of the heart following exercise, a well-known effect. Other examples of causes of this autonomic nervous influence are thyrotoxicosis, which we recognized in 1935, and vagal paralysis by atropine, and probably also the toxic effect of tobacco which two of us (P.D.W. and A.G.) described with Starr in 1938. Fright, with its marked nervous reflex effect, is probably another cause for change in the T waves of this type, as will be reported later by ourselves. Thus the presence of considerable tachycardia should make one suspicious of the possible or probable action of this factor when the T waves are low or even inverted in lead II. The sitting and particularly the standing position favours the development of a relative tachycardia compared with the heart rate in recumbency, and so this naturally may be one reason, but we believe not the major reason, for the change of the T waves in lead II with change in posture. Barker and his associates (1939) have also observed significant lowering of the T waves of the electrocardiogram resulting from overventilation with alkalosis, which, as a symptom of anxiety or hysteria, is met with occasionally. (See addendum on p. 240.)

It is, however, the change in position of the heart in the thorax, which occurs particularly in the case of the vertical or drop heart with the subject in the standing or sitting position, that concerns us particularly here. The T waves in lead II are often simply lower than usual, but sometimes they are flat or diphasic, and occasionally they are actually inverted with a simulation of a diseased state, particularly coronary heart disease. The lateness of the inversion of the T waves adds considerably to this simulation of a disease pattern. There is, however, one T wave pattern, namely, that pictured in Fig. 5, that is almost if not wholly pathognomonic of this positional effect, duplicated rarely if at all by pericarditis or coronary heart disease: that is a late slight notching of the T wave, the notch sometimes scarcely depressing the baseline below its zero position. This finding has been an important clue for us in a number of cases.

It behoves us, therefore, when we encounter flattening, notching, or inversion of the T waves in lead II in apparently healthy persons, especially in those who are young and of a slim build with vertical hearts (the very type who are prone to develop neurocirculatory asthenia and anxiety with overventilation) to take electrocardiograms with the subject in the recumbent (supine) posture as well as sitting, and to be sure that the subject is composed and not excited or fearful. It is also always important to record the position of the body when electrocardiograms are taken for the sake of present and future reference, because

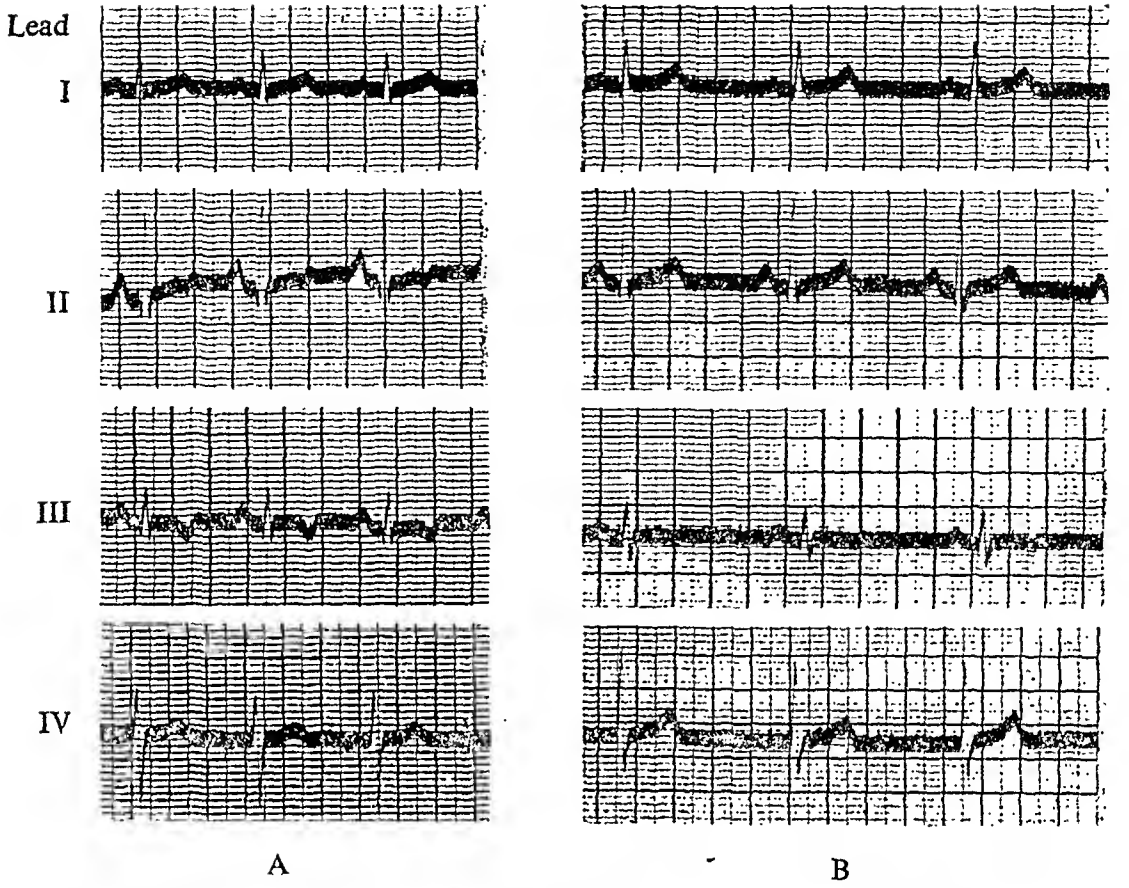

FIG. 5.—Electrocardiographic changes upon change in position from sitting to supine in the case of a woman 45 years old of average build without evidence of heart disease.
(A) Sitting. (B) Recumbent.

of the possible errors in interpretation that may easily arise especially when comparing a series of electrocardiograms. A simple way of recording the position accurately is to draw a straight line which shows whether the thorax is horizontal, vertical, or at a midway angle, thus — | ╲.

Also we should recognize that in these cases posture alone is not the whole answer. It is the position of the heart that counts, and, as has been shown by Scherf and Weissberg and by ourselves, the height of the diaphragm is often very significant, its elevation at full expiration tending to "correct" the T waves, though often not so completely as does recumbency.

Follow-up studies during the past few years, in some cases now extending back nearly ten years, have supported our conviction that the changes we have described in the T waves of lead II are not the result of disease. Our cases have not developed any evidence of abnormality of the heart, and a few who were frail and nervous (with tachycardia) when first seen have grown more robust and composed with improved health in the course of years, and have manifested a "correction" of the T wave variations even in the sitting position; it is probable that a raising of the height of the diaphragm and a decrease in sympathetic overstimulation and hyperventilation account for this

" correction " which was cited but not explained by two of us (P.D.W. and A.G.) in 1935. Also it is, of course, very significant that our most striking cases have been asthenic *young people*.

Finally, this " normal inversion " of the T waves in lead II is quite a common finding. We now recognize several new cases every month in our routine electrocardiographic interpretations and a number of these have been referred to us with the diagnosis of heart disease, often obscure, on the basis of these electrocardiographic findings alone, or with the addition of neurocirculatory asthenia or a physiological heart murmur. Orthostatic hypotension, with tachycardia, in a rare case may be attended by significant T wave inversion, as we have already noted above; whether or not in such cases a decrease in coronary blood flow enters in as a factor we cannot say. It should be realized, of course, that there may be a combination of physiological and pathological factors in the alteration of the T waves in lead II in the same case; a tall lean person may have pericarditis or coronary heart disease or nervous overventilating.

SUMMARY

Inversion of the T waves in lead II of the electrocardiogram, although most commonly the result of heart disease or toxic states, may be a normal physiological variation in occasional persons, particularly those of asthenic habitus with vertical hearts and prone to neurocirculatory asthenia.

The position of the heart is the most important factor in producing this T wave inversion which is found in the sitting or standing position but is corrected by recumbency or by elevating the diaphragm as at full expiration. Autonomic nervous influences comprise another factor, although less striking as a rule, the low or inverted T waves then being attended by tachycardia; any cause of such stimulation, for example, excitement can then be responsible. Fear and anxiety may act through the production of overventilation with resultant alkalosis. Both heart position and nervous influences may be active in the same case.

The relatively common occurrence normally of inversion of the T waves in lead II makes it imperative to recognize its existence in order to avoid erroneous diagnoses of heart disease.

Addendum.—Finally, Mainzer and Krause (1940), described the influence of fear on the electrocardiogram. Immediately before the induction of general anaesthesia, electfocardiographic changes were noted in about two-fifths of 53 cases ; these changes consisted chiefly of S-T depression and lowering or inversion of the T waves similar to that appearing in coronary insufficiency and ascribed by the authors to neurogenic influences reducing the coronary flow.

REFERENCES

Åkesson, S. (1936). *Upsala läkaref. forh.*, **42**, 263.
Barker, P. S., Shrader, E. L., and Ronzoni, E. (1939). *Amer. Heart J.*, **17**, 169.
Graybiel, A., and White, P. D. (1935). *Ibid.*, **10**, 345.
Graybiel, A., Starr, Robert S., and White, P. D. (1938). *Ibid.*, **15**, 89.
Graybiel, A., and White, P. D. (1941). *Electrocardiography in Practice*, Philadelphia.
Leimdörfer, A. (1935). *Med. Klin.*, **31**, 1536.
Mainzer, F. and Krause, M. (1940). *Brit. Heart J.*, **2**, 221.
Scherf, D., and Weissberg, J. (1941). *Amer. J. med. Sci.*, **201**, 693.
Sigler, L. H. (1938), *Amer. Heart J.*, **15**, 146.
White, P. D., and Chamberlain, F. L. (1938). *J. Clin. Invest.*, **17**, 510.
White, P. D., and Chamberlain, F. L. (1938). *New England Heart Association Abstracts.*

PULMONARY VENOUS RETURN VIA THE SUPERIOR VENA CAVA

BY

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From the City General Hospital, Leicester

Received September 16, 1941

The following case is reported as it shows an abnormality which, so far as I am aware, has not been recorded previously. In Abbott's *Atlas of Congenital Cardiac Disease*, 1936, no such case is described, the most closely related one showing pulmonary return into the right auricle via a dilated coronary sinus.

History of the Case

The infant, a female, was born on March 21, 1941. During labour Dr. Hallum, who was in attendance, noted that there was some irregularity of the fœtal heart when bleeding occurred due to a lateral placenta prævia, the os being three quarters dilated. The weight at birth was 6 lb. 11 oz. and the condition was good, although the mother later recalled having been told by the nurse that the child's heart was not right. This observant nurse remains in obscurity. The feet were blue and remained so. When discharged nine days later it is recorded that no murmur was audible and there had been no attacks of cyanosis while in the nursing home.

At home breast feeding was stopped, due to the mother's having " insufficient milk," but bottle feeding was never satisfactory. She vomited practically every time after having taken half the feed, and would become white, with her lips slightly blue or even black. In her ninth week during bathing she appeared breathless and dead beat, but there was no colour change. One day she had a bluish patch on her left cheek. In two months she was only 20 oz. above her birth weight, and was losing. She was taken to a welfare centre, where she was used as a model for a gas-mask demonstration ; immediately after this she was very pale, and remained so until admitted to hospital two days later.

Clinical Findings and Course in Hospital

She entered hospital on May 27, 1941, as a case of inanition for investigation being then nine weeks old.

She was small and undernourished, with marked cyanosis of the extremities,

slight cyanosis of the lips, and a high colour of the rest of the body. Her cry was feeble and almost aphonic. Respirations were 48 per minute, but were not laboured. There was reduplication of the first apical sound and some enlargement of the heart. The liver was palpable and enlarged. When crying, the right side of the mouth was drawn down more than the left. The pulse was regular ; there were no thrills and no pulsation, except slightly at the apex ; there was no bulging of the chest, and the fingers were not clubbed, nor was there tortuosity of the vessels of the eye. The heart rate was regular and 150 per minute ; there was sinus rhythm with no sinus arrythmia. An electrocardiogram showed right axis deviation, large P waves especially in lead II, and inversion of T in leads II and III : these findings suggested auricular and right ventricular preponderance.

The heart was enlarged, and the radiologist reported : " One cannot

FIG. 1.—Radiogram of the heart taken at 6 feet.

exclude a congenital lesion, but there is no definite evidence of its existence." The hæmoglobin was 118 per cent., and the red blood cells 5,410,000 per c.mm. While blood was being taken for examination she became very cyanosed, almost black, and lay back exhausted ; her breathing was not more distressed than normal. After ten to fifteen minutes she gradually became better.

For the first six days feeding was difficult, as she became exhausted, and, on most occasions, would regurgitate half the feed. Cyanosis was not increased. Regurgitation did not occur after this date, although feeding remained difficult. On one occasion after a feed she became purple and distressed. The apex

rate was rapid and regular. Oxygen through a nasal catheter appeared to cause some improvement.

By the ninth day the cyanosis had largely disappeared, although the respiratory rate remained about 60 per minute. The temperature rose to 99·5° F., while the pulse fell to 130 per minute. There were numerous crepitations in both lungs, with diminution of breath sounds and dullness on percussion over the left lung. Sulphapyridine 0·5 g. was given four-hourly. In place of the reduplicated apical first sound there was now a long, coarse, rumbling systolic murmur of fairly low pitch.

On the tenth day her colour was almost normal. The lungs remained very moist and the pyrexia slight. Immediately after the 6 p.m. feed her face became a greyish blue, her lips and ears were black, her face was twitching and her eyes squinting. For some hours she remained grey and exhausted ; her pulse was regular. On the eleventh day her breathing became very distressed, although there was no cyanosis. The appearances were suggestive of laryngeal or bronchial obstruction. She died at 5.30 a.m.

The circulation is shown diagrammatically in Fig. 2.

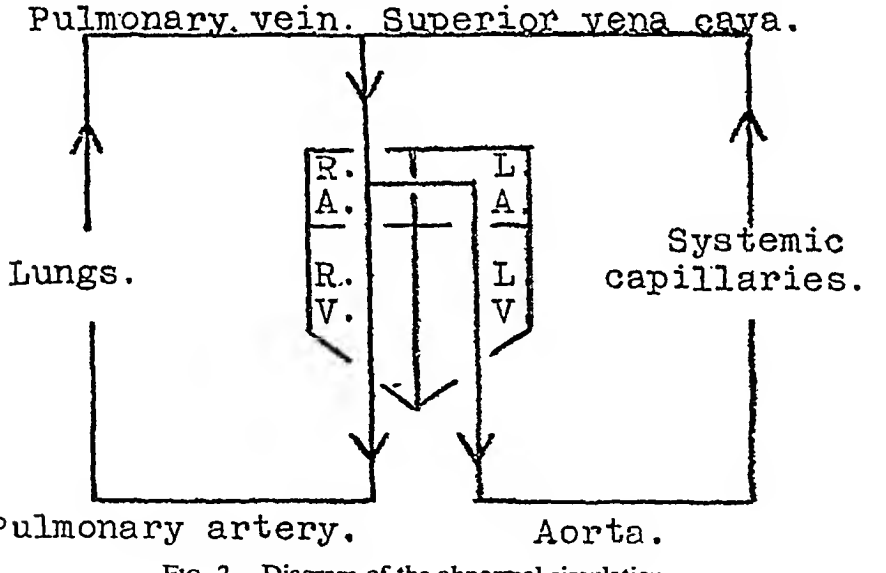

FIG. 2.—Diagram of the abnormal circulation.

POST-MORTEM FINDINGS

There were several ounces of straw-coloured fluid in the pericardial and pleural sacs. The upper two to three feet of the jejunum contained about two ounces of blood mixed with partly digested food. The intestine was very congested. There was no blood in the stomach. The lungs showed mild bronchitis. Macroscopically there were no other abnormalities apart from the heart.

The heart was much enlarged, owing to hypertrophy of the right side, both auricle and ventricle. The heart weighed 52 g. The lungs were joined together by a single pulmonary vein, and from the middle of this arose a thick trunk which united it to the lower and posterior part of the superior vena cava

below the entry of the vena azygos. The pulmonary vein had no direct communication with the left auricle. The hypertrophied right auricle was thus receiving both arterial and venous blood. Many of these points can be well seen in Fig. 3. The sinus venarum was partly separated from the auricle proper by large valves of the superior and inferior vena cava. The pulmonary artery was of great size (about 32 mm. in circumference). The only means of communication between the two sides of the heart was through a small opening (about 11 mm. in circumference) in the upper part of the interauricular septum. This was, presumably, the foramen ovale, despite its high position. The left heart was insignificant in size, forming about one-eighth of the volume of the right heart. The only entry into the auricle was through the opening described. The mitral valve was small but otherwise normal. The aorta was hypoplastic (about 18 mm. in circumference). The ductus arteriosus had closed and was represented by a fibrous cord. Many of these points can be seen in Fig. 4.

FIG. 3.—The anterior aspect of the preparation. The heart has been turned up and to the left so that only the hypertrophied right auricle and part of the right ventricle are seen. The single pulmonary vein is opened longitudinally, and its connection by a thick trunk with the superior vena cava is shown.

FIG. 4.—The posterior aspect of the heart. The lungs have been turned up. The left auricle and ventricle have been fully opened up to show their minute size. The small aorta and the dilated pulmonary vein are in apposition. Above is the single pulmonary vein and its communication with the superior vena cava.

COMMENTS

It appears that during the course of development the trunk formed from the pulmonary veins which enters the middle of the sinus venosus retained connection with the part of the sinus that ultimately becomes the superior vena cava. The part of the sinus venosus that forms the coronary sinus had separated normally. This arrangement would cause no embarrassment to the fœtal circulation, but with the closure of the placental circulation there was admixture of arterial and venous blood, with a consequent strain on the heart. Persistence of a patent ductus arteriosus would not have helped much, as this would have added to the work of the right ventricle.

Despite the persistent venous shunt, the heart maintained life for eleven weeks. Slight exertion was sufficient to produce embarrassment and cyanosis. It is strange that cyanosis was not manifest all the time, and that increased

pulmonary resistance, due to bronchitis, instead of increasing it caused a diminution.

The heart murmurs are difficult to explain. The apparent reduplication of the first apical sound which was heard on admission may have been due to asynchronous ventricular contraction, but this is not supported by the electrocardiogram. The subsequent change in the murmur, with the development of increased pulmonary pressure, and the magnitude of the P wave suggest that it may have been due to auricular systole.

Summary

A case is described in which the only method by which blood could return from the lungs to the heart was through an opening into the superior vena cava. Communication with the left side of the heart was maintained by a patent foramen ovale.

It is believed that this abnormality has not been recorded previously.

I wish to thank Dr. Page, Medical Superintendent, for permission to publish this case. I also wish to thank Dr. Braithwaite, Consulting Physician, and Dr. Ward, Pathologist to the City General Hospital, Leicester, for their help, and Mr. Calder, senior Radiographer to the Royal Infirmary, Leicester, for taking the photographs.

Editorial Note

A case, somewhat related, has been described by T. B. Johnston (1915) *J. Anat. and Phys.*, **49**, 182. The left pulmonary vein opened into the superior vena cava, but the pulmonary vein on the right side was normal. The left pulmonary vein passed upwards (left superior vena cava) and joined the left innominate vein, which passed across to join the superior vena cava.

CHEST LEAD (CR_1) ELECTROCARDIOGRAMS IN AURICULAR FIBRILLATION

BY

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From the Cardiac Department of the London Hospital.

Received October 7, 1941

Lewis (1910) was the first to demonstrate the value of chest leads in displaying the movements of the auricle in auricular fibrillation. A trial of five different leads convinced him that those taken over the right auricle showed maximal auricular oscillations and minimal ventricular complexes which facilitated a study of the auricular waves. In a case of complete heart block Cohn and Lewis (1913) found that oscillations from auricular action were greatest when leads were taken directly from the chest wall, the electrodes being placed in the region of the right auricle. Drury and Iliescu (1921) tried two chest leads in 24 patients with auricular fibrillation. In their first or sternal lead an electrode over the second rib on the right side was paired with one over the seventh costal cartilage on the same side, and in their second or antero-posterior lead an electrode at the centre of the sternum was paired with one at the level of the inferior angle of the scapula, two inches to the right of the spine. They favoured the antero-posterior lead. Holzmann (1937) said that abnormalities of the P wave in the electrocardiogram were best recorded by placing the exploring electrode over the right auricle. Lian and Pinchenzon (1938, 1940) used a chest lead with one electrode over the manubrium and the other in the fifth right intercostal space for the investigation of auricular rhythm, and named it the "precordial auricular lead S5." The application of this lead in one case of arrhythmia, which was thought to be auricular fibrillation, gave a tracing exhibiting large auricular waves. They described the condition as auricular tremulation and maintained that it was intermediary between auricular flutter and fibrillation. They postulated that in fibrillation both the duration and shape of the auricular complex in the cardiogram varied, in auricular flutter there was no variation, and in tremulation it was slight. It was while studying the form of the P wave in the chest lead cardiogram CR_1 * in various cardiac disorders that I became interested in tracings obtained from patients with auricular fibrillation. This lead was

* This designation was suggested by the committee reporting on the standardization of precordial leads (*Amer. Heart J.*, 1938, 15, 235). C is an abbreviation for chest, R for right arm, and the subscript 1 denotes the position of the precordial electrode, namely in the fourth intercostal space at the right border of the sternum.

then recorded in 60 patients in whom clinical examination and the limb lead cardiogram had provided the diagnosis of fibrillation.

It is known that the auricular movements in fibrillation are never faithfully portrayed in the limb lead cardiogram ; the tracing may show no oscillations, or if it does the curves are not constant and vary even in the same patient from insignificant waves to prominent ones, these showing the greatest prominence in one or other lead. When the limb lead cardiograms from the 60 patients were examined for auricular waves they were absent in 28 ; in the remaining 32 the curves were better displayed in leads III and II than in lead I. Actually the oscillations were moderately prominent in lead III in 24 cases, in lead II in 20, and in lead I in 10 cases. Even when distinct coarse waves are seen in limb lead cardiograms they are distorted by movements from sources other than the auricle. In the CR_1 cardiogram extraneous somatic waves are more completely eliminated while the ventricular complexes are small, but its chief advantage over the limb leads appears to be its specificity for recording auricular movements, owing to the plane which the lead traverses. Fig. 1–4 and many

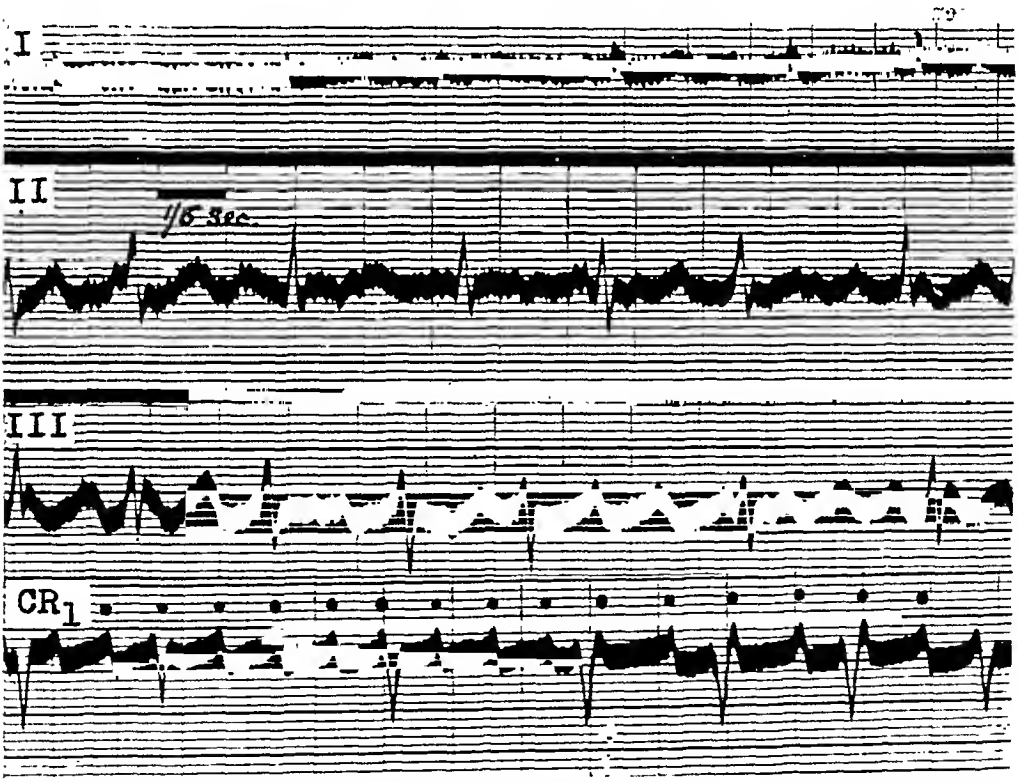

FIG. 1.—Case 29. Auricular fibrillation without apparent cause. Female, aged 64. Auricular rate, 375 a minute. In this and some of the other figures dots denote the summits of the auricular waves.

of the subsequent figures illustrate this. None the less, in many patients this chest lead fails to display the auricular wave to much better advantage than the limb lead. Again, the periodic variation in the amplitude of the oscillations which is characteristic of the limb lead tracings may also be a feature of many of the curves obtained when leading direct from the chest.

In this series 39 CR_1 cardiograms showed large auricular waves (Type I) ; in the remaining 21 the waves were not seen to much better advantage than in the limb lead cardiogram (Type II).

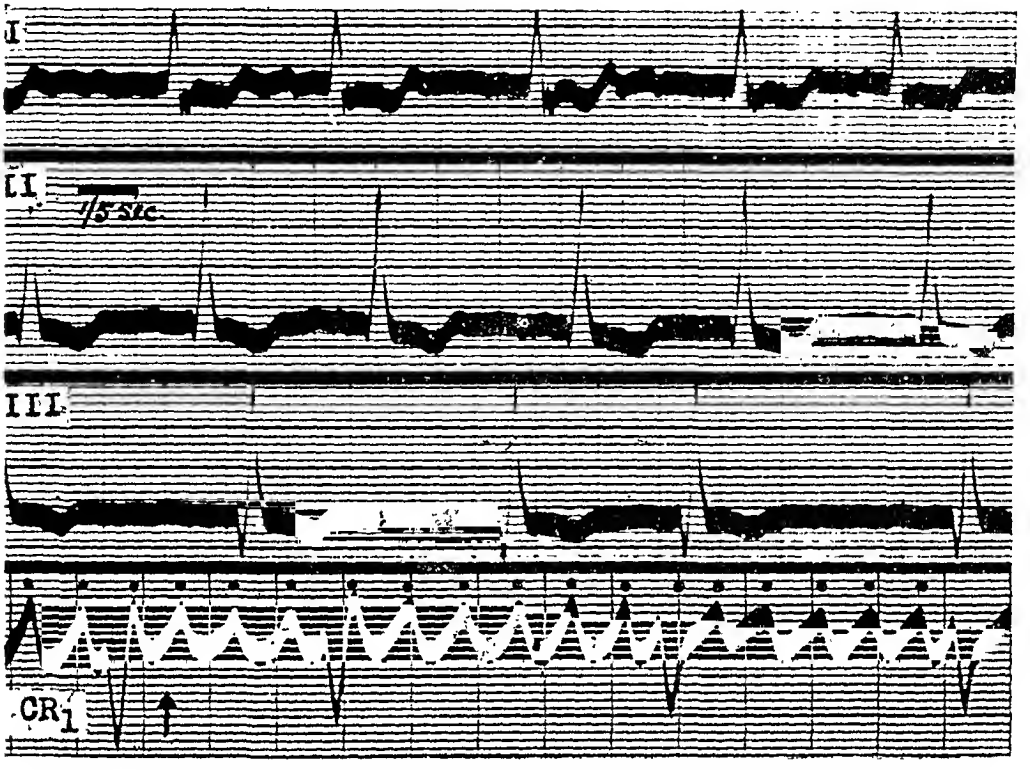

FIG. 2.—Case 22. Auricular fibrillation and mitral stenosis. Female, aged 29. Auricular rate, 384 a minute.

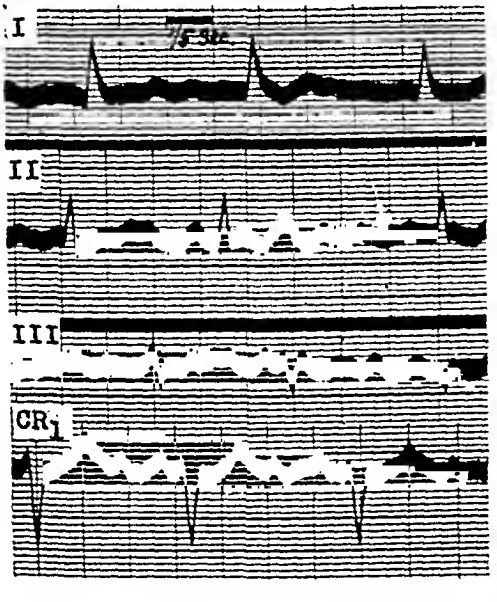

FIG. 3.—Case 25. Auricular fibrillation without apparent cause. Male, aged 53. Auricular rate, 375 a minute.

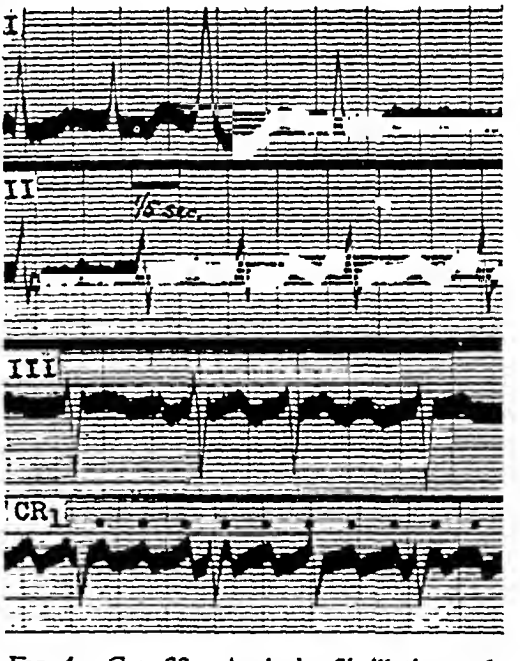

FIG. 4.—Case 32. Auricular fibrillation and mitral stenosis. Female, aged 50. Auricular rate, 362 a minute.

Large Auricular Waves in CR_1: Type I

Although 39 of the 60 patients have been included in this group, 2 (Cases 38 and 39) are kept apart from the remaining 37 and will be discussed at the end of the section.

A description of the auricular wave in the CR_1 cardiogram should relate to its *form*, *rhythm*, and *frequency*, and these features of the curve will now be considered separately.

Form of the Auricular Wave

The form of the auricular wave in the CR_1 cardiogram varied from patient to patient, but it remained fairly constant in the same individual with each curve differing slightly from the other. It did not show that regularity of pattern characteristic of the auricular flutter curve, but there was a close resemblance. In most tracings the fibrillation waves presented a gradual upstroke followed by a rather steep downstroke. The curves were written in continuity and without a pause at the iso-electric level, proving that the auricle was at no time electrically quiescent. Further typical illustrations are given in Fig. 5–9. Often the amplitude of the waves became subject to a phasic variation, from time to time increasing and diminishing in height. During a period when the amplitude of the oscillation diminished (see end of CR_1 tracing in Fig. 5) the wave often became bifid, giving the appearance of two

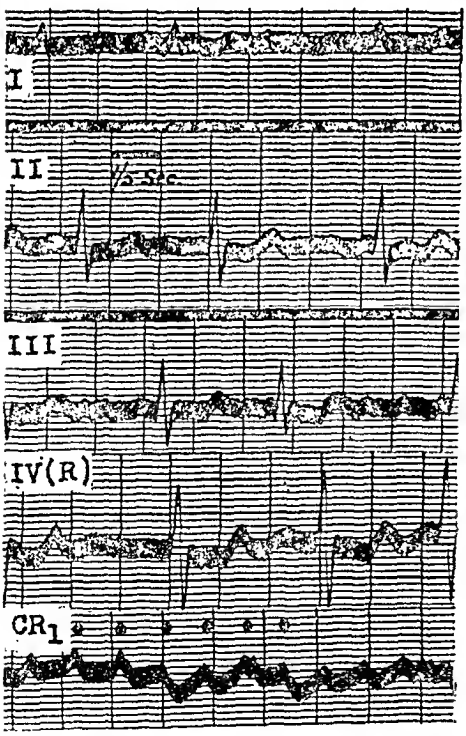

Fig. 5.—Case 17. Auricular fibrillation and mitral stenosis. Male, aged 44. Auricular rate, 394 a minute. Bifid auricular wave at end of CR_1 lead.

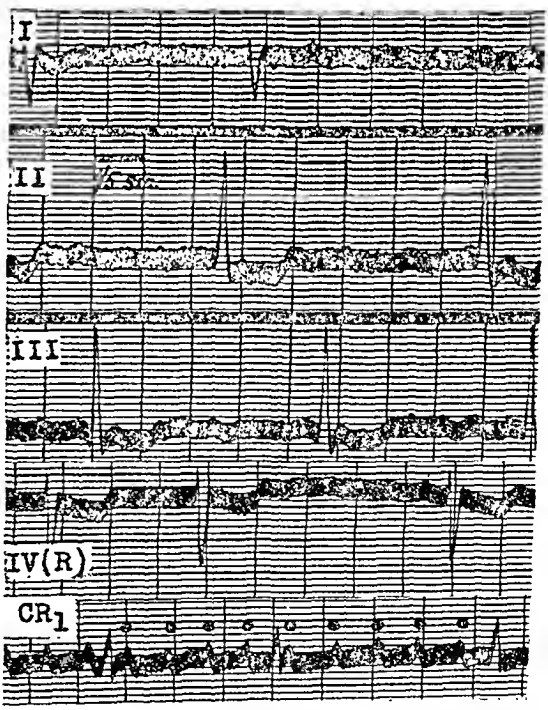

Fig. 6.—Case 31. Auricular fibrillation and mitral stenosis. Female, aged 22. Auricular rate, 363 a minute.

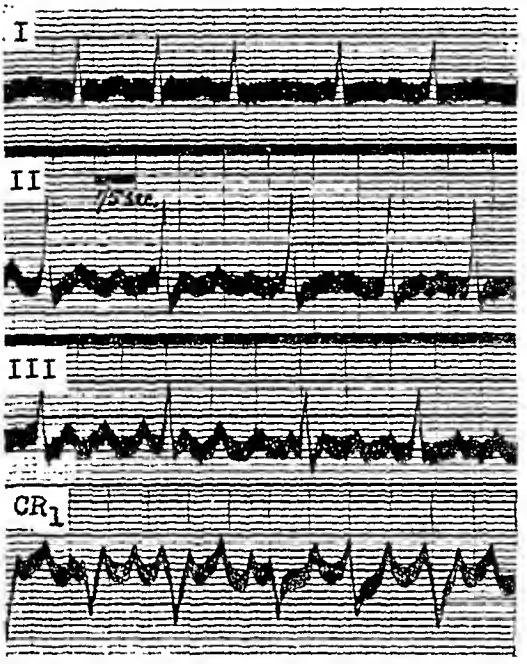

FIG. 7.—Case 36. Auricular fibrillation and thyroid toxæmia. Male, aged 55. Auricular rate, 350 a minute.

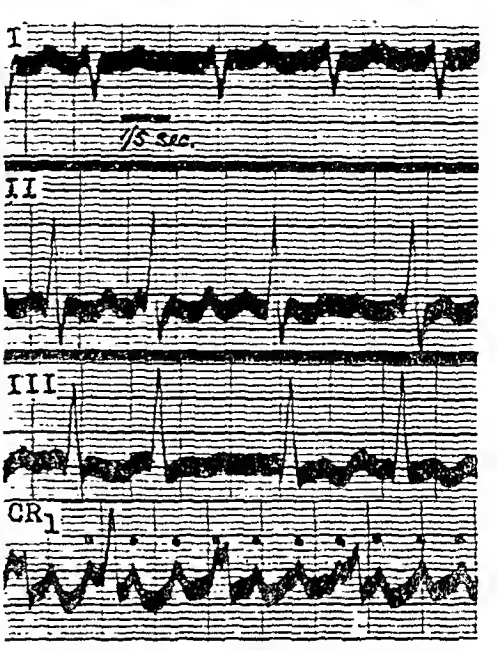

FIG. 8.—Case 18. Auricular fibrillation and mitral stenosis. Female, aged 25. Auricular rate, 394 a minute.

separate waves. No extrinsic cause for this variation could be made out; the respiratory movements, for instance, did not influence the amplitude, and the same observation was made by Drury and Iliescu (1921). When comparing five different chest leads, Lewis (1910) stated that the oscillations were conspicuous or the reverse according as the contacts were close to or distant from the right auricle, but that whenever conspicuous oscillations were obtained, then inconspicuous oscillations appearing in part of the tracing were an expression of some intrinsic variation in the auricle. In my cases the amplitude of the fibrillation wave did not depend on the condition initiating the arrhythmia nor on the size of the right auricle, for the waves were no larger in patients with mitral stenosis than in those without, who were seen on radioscopy to have a heart unaffected in shape or in size (Fig. 1 and 3).

Rhythm of the Auricular Wave

Describing the oscillations that replace the normal P waves when auricular fibrillation sets in, Lewis (1925) stated that they were never quite regular in form, amplitude, or length. The 37 patients in this series may be divided into three groups according to the rhythm of the fibrillation waves in the CR_I electrocardiogram. There were 18 patients in the largest group where the rhythm was irregular; even in these the irregularity was not obvious at first and only emerged when measurements were taken. It was difficult to determine the influence of the ventricular systole or diastole on the auricular rhythm in these cases. In the second group of 13 patients the rhythm of the auricular

waves was regular except when it was disturbed (occasionally, frequently, or constantly) by ventricular systole; in 7 the auricular wave succeeding ventricular systole was delayed, and in 6 it was hastened. This finding is in disagreement with that of Drury and Iliescu (1921), who stated that both ventricular systole and diastole were without effect on the auricular oscillations. The third group held 6 patients in whom the rhythm of the auricular waves was regular and was undisturbed by ventricular systole ; in these patients although the auricular rhythm was regular and very like auricular flutter, the shape of the waves differed slightly from beat to beat.

Frequency of the Auricular Wave

Different rates have been assigned to auricular contraction in auricular fibrillation by different writers. Thus, Battro (1937) mentions 400 to 600

TABLE I

37 PATIENTS WITH LARGE AURICULAR WAVES IN THE CR_1 CARDIOGRAM (TYPE I)

Case No.	Age	Cause of Fibrillation	Digitalis or No Digitalis	Average Ventricular Rate	Auricular Rate	Limb leads showing Fibrillation Waves
1	64	No cause found	No D.	100	488	II and III
2	63	Mitral stenosis	No D.	100	453	0
3	60	No cause found	D.	100	450	II and III
4	43	Mitral stenosis	D.	90	450	0
5	34	No cause found	No D.	85	450	III and II
6	30	Mitral stenosis	D.	37	437	0
7	45	do.	D.	75	436	II and III
8	45	do.	D.	85	428	0
9	39	do.	D.	130	428	II and III
10	33	do.	D.	70	420	I
11	26	do.	D.	30	416	0
12	68	Hypertension	No D.	150	409	II
13	38	Mitral stenosis	No D.	92	400	III and II
14	58	No cause found	No D.	130	400	III
15	63	Hypertension	D.	90	400	0
16	46	Mitral stenosis	D.	60	400	III and II
17	44	do.	No D.	100	394	0
18	25	do.	D.	120	394	II
19	29	do.	D.	55	390	I
20	37	do.	D.	100	388	I
21	76	Hypertension	No D.	75	385	III
22	29	Mitral stenosis	D.	100	384	0
23	66	do.	D.	130	375	II and III
24	53	do.	D.	66	375	0
25	53	No cause found	No D.	85	375	III and II
26	38	Mitral stenosis	D.	85	375	II
27	31	do.	D.	130	375	0
28	39	do.	D.	120	375	I, II, and III
29	64	No cause found	No D.	120	375	III and II
30	51	Mitral stenosis	D.	64	375	II and III
31	22	do.	D.	85	363	0
32	50	do.	D.	150	362	II and III
33	43	do.	D.	75	362	II
34	39	do.	D.	72	355	0
35	27	do.	D.	66	353	I and III
36	55	Thyroid toxæmia	No D.	130	350	III and II
37	49	Mitral stenosis	D.	75	350	I

and Bramwell (1932) 500 to 600. Drury and Iliescu (1921) found the auricular rate to be 390 to 588 in twenty-four cases (chest leads), with an average of 473. Herrmann (1936) stated that it was 450 to 600, Levine (1936) 400 or more, Lewis (1925) rarely below 400 and rarely above 600, Pardee (1928) 350 to 500, Wenckebach and Winterberg (1927) 434 in one patient with chest lead, and White (1937) gave the figure as 400 to 600. The disparity in the figures is explained by the fact that the observations have been based in most instances on the frequency of the auricular waves in the limb lead cardiogram. Such observations are necessarily precarious, owing to the imperfections of this electrocardiogram in showing the complete details of auricular contraction. Thus, in calculating the rate of the main movement of the auricle both the coarse and the fine oscillations have been separately regarded as depicting auricular contraction. This impression of greater frequency created by notching or splitting of the main auricular wave is illustrated towards the end of the CR_1 tracing in Fig. 5. Again, even if the oscillations in the limb lead cardiogram are moderately distinctive for a moment calculation of the auricular rate based on a few beats will be inaccurate. Table I shows the remarkable constancy of the rate of auricular contraction in patients with auricular fibrillation.

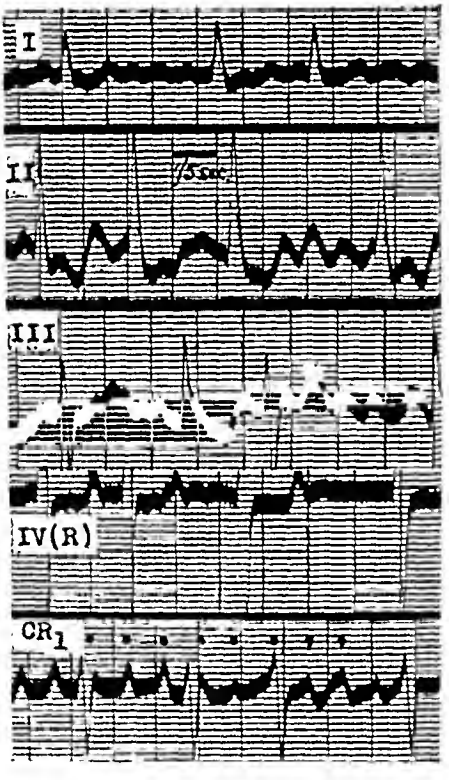

FIG. 9.—Case 9. Auricular fibrillation and mitral stenosis. Female, aged 39. Auricular rate 428 a minute.

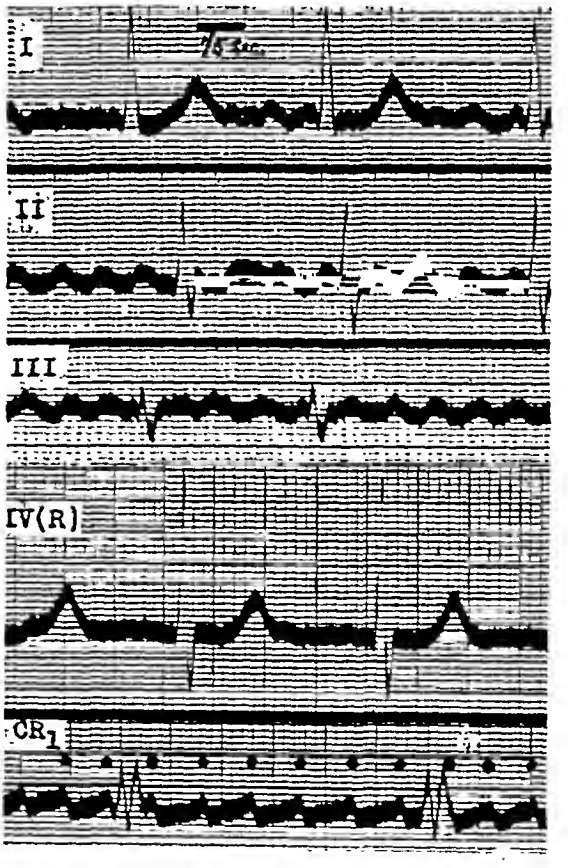

FIG. 10.—Case 38. Mitral stenosis. Male, aged 43. Auricular rate, 312 a minute. Limb leads suggest auricular fibrillation. The CR_1 lead shows auricular flutter (see text p. 254).

R

More than half had an auricular rate of 375 to 400 a minute ; with two exceptions the rate was 350 to 450, and the average rate was 400 for the 37 patients. The auricular rate did not depend on the ventricular rate, for a patient showing the highest auricular rate (488) had an average ventricular rate of 100, while a patient with the lowest auricular rate (350) had a ventricular rate of 130. Digitalis was found to have no effect on the auricular rate in patients re-examined with the CR_1 electrocardiogram during a period of digitalis therapy. Quinidine did slow the auricular rate (see Fig. 12).

Two patients (Cases 38 and 39) were regarded clinically as auricular fibrillation and mitral stenosis. In Case 38 the limb lead cardiograms supported this view, although the tracing in some ways resembled flutter : the CR_1 cardiogram, however, gave the diagnosis of auricular flutter (Fig. 10). In Case 39 the ventricular complexes were infrequent and usually irregular, and no auricular waves were visible ; in all, 15 limb lead cardiograms were recorded, and they appeared to support the diagnosis of auricular fibrillation. The CR_1 cardiogram still left doubt about the exact diagnosis of the type of auricular activity but showed 2 : 1 auriculo-ventricular block (Fig. 11). This last tracing shows a rhythm similar to that found in chest lead cardiograms in paroxysmal tachycardia, which are being investigated.

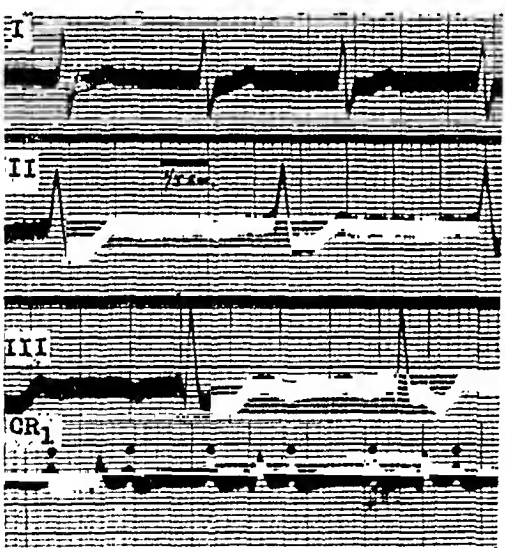

FIG. 11.—Case 39. Mitral stenosis. Female, aged 52. Limb leads suggest auricular fibrillation, but CR_1 shows that whatever the auricular rhythm may be there is 2 : 1 auriculo-ventricular block. Auricular rate, 210 a minute.

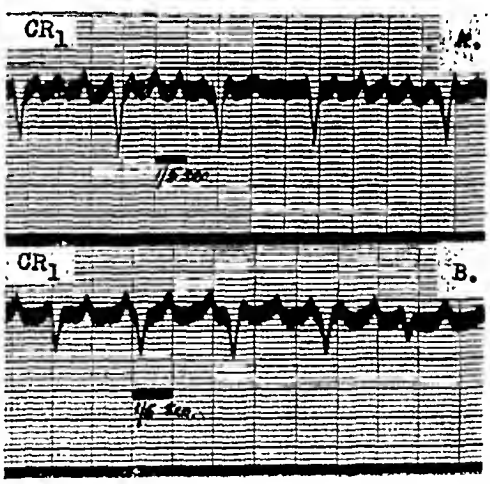

FIG. 12.—Slowing of the auricular rate by quinidine. The tracing above was taken before, and that below after, a week on quinidine (9 grains daily). The auricular rate was reduced from 375 to 340 a minute.

SMALL AURICULAR WAVES IN CR_1 : TYPE II

In most of the 21 patients of this group the CR_1 cardiogram demonstrated auricular waves which were more conspicuous than those recorded in the limb lead cardiogram, but the curves were neither prominent nor constant enough to permit a study of the form of individual waves nor to allow an

estimate of the rate of auricular contraction. An attempt was made to discover some factor that might determine whether a patient with auricular fibrillation would show large (Type I) or small (Type II) auricular movements in the CR_1 cardiogram. To this end special attention was paid to the cause and duration of the arrhythmia, the ventricular rate, digitalis influence, the size of the right auricle, presence of " fibrillation " waves in the limb lead cardiogram, thickness of the chest wall, and to the possibility of a faulty technique in applying the chest electrode.

The *cause* of the arrhythmia appeared to have no influence in deciding the amplitude of the auricular wave in the CR_1 cardiogram. In the favourable series (Type I) of 37 patients, mitral stenosis was the cause in 27, hypertension in 3, thyroid toxæmia in 1, and cause unknown in 6. In the unfavourable series (Type II) of 21 patients, mitral stenosis was the cause in 18, and the etiology was unknown in 3.

An attempt was made to ascertain the *duration* of the fibrillation in each patient. From this inquiry the prominence of the auricular wave did not appear to depend on the duration of fibrillation ; the arrhythmia appeared to be recent (within three months) in 14 of 37 Type I cases and in 6 of 21 Type II cases.

TABLE II

21 PATIENTS WITH SMALL AURICULAR WAVES IN THE CR_1 CARDIOGRAM (TYPE II)

Case No.	Age	Cause of Fibrillation	Digitalis or No Digitalis	Average Ventricular Rate	Limb leads showing Fibrillation Waves
1	60	No cause found	No D.	60	0
2	48	Mitral stenosis	No D.	85	III and I
3	39	do.	D.	60	0
4	34	do.	D.	80	0
5	55	do.	D.	94	0
6	21	do.	No D.	42	0
7	54	do.	D.	60	0
8	44	do.	D.	55	0
9	51	do.	D.	50	0
10	45	do.	D.	85	0
11	39	do.	D.	42	0
12	58	do.	D.	90	0
13	48	do.	D.	50	0
14	42	do.	D.	55	0
15	48	do.	D.	90	III and I
16	68	No cause found	D.	85	III
17	60	do.	D.	85	0
18	34	Mitral stenosis	D.	42	I and III
19	58	No cause found	No D.	66	III
20	58	Mitral stenosis	D.	46	0
21	44	do.	D.	60	III, II, and I

When the *ventricular rate* was compared in patients in the two groups a difference was observed. It was much more rapid in those with prominent auricular waves, averaging 92 per minute for the 37 patients (see Table I), compared with 66 for the 21 patients with inconspicuous waves (see Table 2).

Again, whereas no Type II patient had a rate higher than 94, in Type I patients it was over 100 per minute in 17. Nevertheless, although conspicuous auricular waves were always present when the ventricular rate was rapid, they were sometimes observed with a moderately slow ventricular rate (Fig. 3).

The inquiry on rate led to an investigation of the incidence of *digitalization* in patients in each group. Although it was a little commoner in Type II patients, the influence of digitalis on the auricular wave was not obvious.

It was natural to assume that in Type I patients a projection of the *right auricle* beyond the right border of the sternum favoured the recording of auricular movements by an electrode placed in this area. Lewis (1910), when advocating the more frequent use of chest leads in the study of oscillations produced by the fibrillating auricle, stated that the best curves were obtained in cases in which the right auricle was distended, as in mitral stenosis, when a large part of its surface lay in contact with the chest wall. The present investigation does not support this view, for it showed that conspicuous auricular waves in the CR_1 electrocardiogram did not depend on extension of the heart to the right. Thus, most of the patients were examined by radioscopy, and in 15 patients showing conspicuous waves enlargement of the right auricle was either absent or slight, whereas in 9 patients showing inconspicuous waves right auricular enlargement was either moderate or considerable.

That patients with prominent fibrillation waves in the limb lead electrocardiogram would also show conspicuous waves in the CR_1 was expected, and this proved to be the case, so that coarse auricular oscillations were seen in one or more limb leads in 25 of the 37 Type I cases and they were absent in 15 of the 21 Type II cases. At the same time the exceptions emphasize that this criterion is not a constant guide in predicting the two types.

The thickness of the chest wall did not affect the amplitude of the auricular waves in the CR_1 electrocardiogram, and that inconspicuous curves were not the result of a faulty technique in applying the chest electrode was proved by recalling patients of both series and obtaining in them tracings identical with the previous records.

Summary and Conclusions

The chest electrocardiogram, CR_1, was taken in 60 patients with auricular fibrillation in order to study the auricular wave. Large and conspicuous waves, resembling those of auricular flutter, were found in 39 patients (Type I). In the remaining 21 cases (Type II) the auricular waves were small and no more conspicuous than in many limb lead electrocardiograms.

No factor was discovered that determined in a patient with auricular fibrillation whether the auricular movements would be represented in the CR_1 cardiogram by large or by small waves, except that if the ventricular rate was high and the auricular oscillations were conspicuous in the limb lead cardiogram, distinct waves were likely to show in the CR_1 cardiogram. The ætiology and the duration of the arrhythmia, the size of the right auricle, digitalization

or its absence, and the thickness of the chest wall, did not seem to decide whether a patient would exhibit large (Type I) or small (Type II) auricular waves.

The features of the auricular waves were clearly shown in those patients classified as Type I, and these were specially studied. The *form* of the wave, varying slightly in different patients, resembled the waves found in auricular flutter, although lacking the same constant pattern. The waves recurred continuously without a pause at the iso-electric level, and each showed a gradual upstroke followed by a steeper downstroke. The amplitude of the wave was occasionally subject to a natural variation, and this was independent of any known extrinsic factor, including respiration. Small waves were often bifid, thereby giving the appearance of two waves and explaining the more frequent oscillations seen in the limb lead cardiogram. The wave was no larger in mitral stenosis than in non-rheumatic auricular fibrillation.

The *rhythm* of the auricular waves was slightly irregular in 18 patients, regular in 13 except for interruptions by ventricular systole when the succeeding auricular wave was as often delayed as quickened, and quite regular in 6 cases, where the rhythm was undisturbed even by ventricular systole, so that the tracing closely resembled that of auricular flutter.

The *frequency* of auricular waves in auricular fibrillation was found to be reasonably constant ; the rate was 375 to 400 per minute in more than half the cases ; with two exceptions the range was 350 to 450 and the average rate for all patients was 400. Higher rates of auricular contraction generally assigned to auricular fibrillation have been based on observations on limb lead cardiograms which often contain more than one oscillation representing a single beat of the chest lead cardiogram. The rate was uninfluenced by digitalis but it was reduced by quinidine.

In two patients in whom a clinical diagnosis of auricular fibrillation was supported by a limb lead cardiogram, the CR_1 tracing demonstrated auricular flutter in one and 2 : 1 auriculo-ventricular block in the other. The value of this chest lead is also seen in elucidating cases of so-called impure flutter, better regarded as fibrillation, and in the interpretation of records with auricular waves in the limb lead cardiogram sometimes subdued or obscured, as in heart block and in paroxysmal tachycardia.

The chest, CR_1, cardiogram permits the limited definition of *auricular fibrillation* as a succession of waves at a rate of about 400 per minute, differing slightly in size and shape, and with a rhythm almost as often regular as irregular. The ventricular responses in fibrillation have no constant relationship to the auricular waves, probably because the auricular rate is too high for any regular control.

In contrast *auricular flutter* shows a succession of waves at a rate of about 300 per minute, identical in size and shape, and perfect in rhythm. The ventricular responses in flutter are determined by the auricular waves giving a fixed or varying ratio.

I wish to thank Dr. John Parkinson, Physician to the Cardiac Department of the London Hospital, for his helpful criticism of this paper.

References

Battro, A. (1937). *Las Arritmias eb Clinica*, Buenos Aires.
Bramwell, C. (1932). *Heart Disease*, London.
Cohn, A. E., and Lewis, T. (1913). *Heart*, **4**, 15.
Drury, A. N., and Iliescu, C. C. (1921). *Heart*, **8**, 171.
Herrmann, G. R. (1936). *Synopsis of Diseases of the Heart and Arteries*, London.
Holzmann, M. (1937). *Arch. Kreisl Forsch.*, **1**, 1.
Laufer, S. (1935). *Arch. Mal. Cœur*, **28**, 98.
Levine, S. A. (1936). *Clinical Heart Disease*, London.
Lewis, T. (1910). *Heart*, **1**, 306.
—— (1925). *The Mechanism and Graphic Registration of the Heart Beat*, 3rd ed., London.
Lian, C., and Pinchenzon, B. (1938). *Cardiologia*, **2**, 56.
Lian, C., and Pinchenzon, B. (1940). *Medical Annual*, Bristol (Abstract).
Pardee, H. E. B. (1928). *Clinical Aspects of the Electrocardiogram*. 2nd ed., London.
Wenckebach, K. F., and Winterberg, H. (1927). *Die unregelmässige Herztätigkeit*, Leipzig.
White, P. D. (1937). *Heart Disease*, 2nd ed., New York.

PROCEEDINGS OF THE CARDIAC SOCIETY OF GREAT BRITAIN AND IRELAND

The FIFTH ANNUAL GENERAL MEETING of the Cardiac Society of Great Britain and Ireland was held at the School of Geography, Oxford, on Friday, April 18, 1941.

CHAIRMAN: A. G. GIBSON

36 Members and 8 Visitors were present
The Chairman took the chair at 10.15 a.m.

PRIVATE BUSINESS

1. The minutes of the last meeting were read and confirmed.
2. The accounts, audited by Evan Bedford and Curtis Bain, were presented by the Council and approved, the balance being £66 4*s.* 11*d.*
3. The Secretary proposed on behalf of the Council and the Society approved the following addition to Rule 11
   " In exceptional circumstances the Council may release a Member from this rule."
4. The Chairman proposed on behalf of the Council, and the Society agreed
   " that in view of the importance of keeping the Society in being during the war, Rule 23 should be in abeyance and that the Secretary should be asked to continue in office, although he would have completed five years after the 1941 meeting."
5. On the recommendation of the Council, it was decided to ask the following to accept nomination as Honorary Members: J. B. Herrick, Chicago, U.S.A., and Frank N. Wilson, Ann Arbor, U.S.A.
6. Five Associate Members were elected Ordinary Members; two new Associate Members were elected; and ten Associate Members were re-elected for another period of three years.
7. Crighton Bramwell, Manchester, and Henry Moore, Dublin, were elected members of the Council for the years 1941–45.
8. The Secretary reported that:—
   (1) since the last meeting the Council had heard with regret of the death of three Honorary Members—
      Maud Abbot of Canada,
      Karel Frederik Wenckebach of Vienna, and
      Charles Laubry of Paris;
   (2) the Committee appointed at the request of the Ministry of Labour and National Service to advise on the instructions for the examination of the cardiovascular system of recruits had reported to the Ministry, and that the report had been accepted in part;
   (3) the Council had appointed a Committee to consider the question of members from other parts of the British Empire;
   (4) the Journal Board of the British Medical Association had written expressing

their satisfaction with the continuation of the British Heart Journal under the difficult conditions of the War; and

(5) the Council had appointed Shirley Smith as Assistant Secretary for another year and wished to thank him for his services during the last year.

Discussion on Early Signs of Cardiovascular Disease (*Morning Session*)

Chamberlain opened the discussion on the early signs of *valvular* heart disease. Auscultation was still the method of diagnosis of paramount importance, diastolic murmurs in aortic regurgitation and mitral stenosis establishing the diagnosis with certainty in most cases. There were certain other clinical, electrocardiographic, and radiological signs, some of which in combination might be sufficient to establish a diagnosis of valvular disease without the characteristic murmur.

In *mitral stenosis* the clinical signs usually emphasized were accentuation or reduplication of the mitral first, pulmonary second, or mitral second sounds. An abrupt loud mitral first was the most constant associated clinical sign in mitral stenosis and was of more importance when the heart rate was slow. Accentuation of the pulmonary second was a much less constant phenomenon in early cases of mitral stenosis though common in the more advanced ones, whilst accentuation of the mitral second was rather uncommon. Reduplication, though common in the pulmonary second, was not a constant or a particularly helpful sign. The electrocardiogram frequently showed no changes, but a split P wave, especially of low voltage, was such a common sign in mitral stenosis that it was worthy of consideration in doubtful cases, especially when associated with the less common right ventricular preponderance.

Enlargement of the left auricle, seen best on screening in the right (I) oblique view after a barium swallow, and prominence of the pulmonary arc were important radiological signs; the latter was an earlier and more constant sign than auricular enlargement.

The diagnosis of *aortic stenosis* was debateable. Some held that the characteristic anacrotic pulse associated with a harsh systolic murmur (with or without a thrill) over the aortic area and conducted into the neck was essential for diagnosis. For others a harsh murmur and thrill were alone acceptable. Some of the latter cases proved eventually to be due to genuine stenosis and when left ventricular hypertrophy was present the presumptive diagnosis might be justified even in the absence of an anacrotic pulse, for such a pulse indicated a well-developed aortic stenosis.

For the diagnosis of *aortic regurgitation* auscultation still remained the principal method. The basal diastolic murmur might long precede other clinical or instrumental methods of diagnosis. The aortic second sound was rarely abolished until regurgitation was free and the vascular phenomena were late in appearance.

Terence East discussed the early signs of *hyperpietic* disease.

Changes in the arterial system and in the heart could only be regarded as late signs, so the early diagnosis would depend on the interpretation of the readings of the sphygmomanometer.

The chief difficulty lay in distinguishing the transient rise in blood pressure due to nervousness from the true early high blood pressure. On the whole the diastolic pressure was a safer guide than the systolic because it was less labile. Nervousness might cause rise in pulse rate and not in pressure, and vice versa. The diastolic pressure might sometimes be unreadable. In doubtful cases raising the arm might give a clearer diastolic reading. In any borderline case the more readings the better. Even quite a long time spent waiting recumbent would not always bring a nervous rise down. The way the heart beats was perhaps the most constant indication of the

degree of nervousness. In borderline cases suspicions of hypertension might be confirmed by overweight, by the personal appearance, and by the family history. If 160 to 150 systolic and 95 to 100 diastolic were taken as the border zone, the interpretation of the figures would depend on as many other factors as possible, and must often remain a matter of opinion, the correctness of which only time would show.

BRUCE PERRY spoke on the early signs of *myocardial* disease.

The early signs of damage to the myocardium varied considerably according to the ætiology of the myocardial lesion. In diphtheria, conduction defects were often the first evidence of pathological processes. In acute rheumatism, the mitral regurgitant murmur due to the dilated mitral ring was the usual first evidence of myocarditis followed rapidly by evidence of cardiac enlargement. In the other types of heart disease, thyrotoxic, hypertensive, and senile, the first evidences of involvement of the myocardium were usually the symptoms of cardiac insufficiency. Here the importance of dyspnœa was paramount, and it became of considerable value to be able to distinguish dyspnœa arising from cardiac insufficiency from that resulting from other causes. An estimation of the arm–tongue circulation time had proved of considerable value in this, though this was generally an indication of the onset of failure. The great difficulty in accepting minor changes in the electrocardiogram or in the X-ray picture of the heart as early evidence of myocardial damage lay in the wide variation met with under normal conditions.

SHORT COMMUNICATIONS

THE RIGHT PECTORAL ELECTROCARDIOGRAM IN AURICULAR FIBRILLATION

WILLIAM EVANS showed how well the auricular movements in auricular fibrillation are displayed in the right pectoral electrocardiogram. When this lead was recorded in 42 cases of auricular fibrillation conspicuous auricular waves were seen in 25, but in the remaining 17 patients they were not seen to better advantage in this lead than in limb leads.

A study of the favourable tracings showed that the form of the auricular waves, although not so completely regular as the waves of flutter, was remarkably uniform. In more than one-half the cases the wave recurred regularly, and in the others the irregularity was slight; it occurred at intervals and was sometimes associated with ventricular systole. The rate of auricular contraction in the majority was slower than 400 a minute which was the average for all the cases. Occasionally the right pectoral lead showed typical flutter in patients previously regarded as instances of fibrillation following clinical examination and limb-lead electrocardiography. Further the application of this chest lead in patients believed to have simple paroxysmal tachycardia will sometimes demonstrate the arrhythmia to be auricular flutter, and an example of this was exhibited.

(Published in full on p. 247)

THE COLLATERAL CIRCULATION IN COARCTATION OF THE AORTA

CRIGHTON BRAMWELL and A. MORGAN JONES

(Published in full: see p. 205)

THE HÆMIC FACTOR IN ANGINA PECTORIS

B. T. PARSONS-SMITH described some cases illustrating the hæmic factor in angina pectoris, and discussed the factors involved.

Coronary sclerosis was the basis of myocardial ischæmia in 80–90 per cent of

cases. Myocardial anoxæmia might be produced also by various types of anæmia and possibly also by polycythæmia, and these syndromes might be curable by treatment. He recounted the details of three patients suffering from chronic hæmorrhagic anæmia, hypochromic anæmia, and pernicious anæmia. In the last case anginal symptoms had developed, and in each case the repair of the anæmia had abolished the angina. The importance of blood counts in difficult cases of angina pectoris was illustrated by these clinical examples. The existence of pernicious anæmia might remain unsuspected until the later stages of its development.

The Electrocardiogram of the Stokes-Adams Attack

John Parkinson and Cornelio Papp (*introduced*)

(Published in full: see p. 171)

"Chronic Myocarditis"

John Hay urged that the words "chronic myocarditis" should not be used as a diagnosis because he considered it misleading. Myocarditis should signify an inflammation of the myocardium, and admittedly there were sound reasons for the term chronic rheumatic myocarditis when referring to the advanced phases of a rheumatic infection.

In the later decades of life, however, myocardial fibrosis was circulatory in origin and degenerative rather than inflammatory. He feared that the teachers in medicine and the writers of text-books were very largely responsible for the persistence of this term and quoted several examples from well-known books, illustrating the loose and confusing use of the term. The pathologists were also to blame; one referred to "so-called fibrous myocarditis." Another wrote that obliteration of a branch or branches of a coronary artery was the "most common cause of cardiac fibrosis, or as it is usual to term it 'interstitial myocarditis.'" Similarly in books dealing with electrocardiography, one finds "Myocarditis, Chronic" used almost as an equivalent of "Myocardial Disease" or "Myocardial Damage."

There was no need to multiply instances. It seemed quite clear that one writer after another had timidly refused to discard this unsatisfactory nomenclature because others were equally timid.

It might be true that in the production of ischæmic fibrosis changes occurred that might legitimately be termed inflammatory, but he was convinced that to call such a pathological product myocarditis was to mislead. Cardio-sclerosis was a clearer and more appropriate term.

He felt that the Society as a whole should refrain from perpetuating such a muddling and misleading phrase as chronic myocarditis, except in those cases such as rheumatic carditis, where it might be justified.

Discussion on the Treatment of Coronary Thrombosis (*Afternoon Session*)

The speakers had been asked to consider if the orthodox treatment was all essential and based on sound principles.

Curtis Bain introduced the discussion and suggested that the period of rest in bed might be reduced to three weeks, provided that

(*a*) the patient had had no previous attacks;

(*b*) there had been no significant fall in blood pressure, no fever, and no pericarditis; and

(*c*) there were no complications. He recognised that this suggestion would be provocative of discussion.

For treatment of the painful phase intravenous morphia was valuable; it would

stop the pain in about 3 minutes. One sixth of a grain should be injected intravenously, followed at once by one quarter hypodermically and later by another quarter, if required. Other drugs included theophylline-ethylene-diamine (Cardophyllin). It could be given intravenously in emergencies such as pulmonary œdema or complete heart block. Although useless in true shock following coronary thrombosis, respiratory stimulants such as coramine might revive certain patients who passed into a condition of pseudo-shock. *Oxygen therapy* was of undoubted use in those cases where the pain had persisted in spite of adequate doses of morphia and in those in whom cyanosis developed at any stage of the illness. The small open-top type of oxygen tent were well tolerated.

Digitalis should be reserved for those cases in whom cardiac failure with œdema developed. Auricular fibrillation was paroxysmal in type and the paroxysms usually subsided naturally without causing difficulty. In severe cases fibrillation might be present from the outset, but in these it was doubtful whether a myocardial poison such as quinidine would not do more harm than good.

The *dietetic regime of under-nourishment* was introduced by Masters. It aimed at reducing the work of the heart by lowering the basal metabolic rate with a concomitant fall in the pulse rate. Upward pressure from flatulent distension of the stomach was avoided. The diet was maintained for the whole period during which the patient was in bed and increased gradually thereafter. The diet suggested by Masters had been found to be rather severe, but a diet consisting of carbohydrates 100 g., proteins 45 g., and fats 35 g. has been well tolerated, and the results from it had been satisfactory.

JOHN HAY visualized three stages in the treatment of coronary thrombosis. The first was the stage of onset with pain and shock. The second or intermediate stage was that of healing. Thirdly, at the end of three or four months the softened necrosed area had been replaced by scar tissue, and this was the period in which the cardiac reserve had to be built up and the patients' limitations defined.

A few days after the onset the pain was in abeyance, and the symptoms of shock had disappeared and the patient—when at rest—was comfortable, though often apprehensive.

As the production of a sound scar takes at least three months, so the patients' activities must be supervised for that period and kept well within safe limits, more especially in the first few weeks.

To obtain a leisurely heart rate with no sudden stresses or cardiovascular excitement (leaving to nature the business of repair), mental excitement, restlessness and apprehension are to be mitigated; veganin, theominal, or bromides are useful in producing mental calm, and a more philosophic outlook. For the first three or four days the patient needs only fluids such as weak tea, orange juice, lemonade, and drinks containing glucose or honey. Later, a light mixed diet can be given, but each meal should be small and appetising, and any food tending to produce flatulence avoided.

For the first two weeks the patient should be fed by the nurse. If pyrexia is present or if *congestive cardiac failure* has developed the nourishment should be limited to one and a half pints of skimmed milk per diem, and as the indications of cardiac failure diminished a gradual return to light, mixed, easily digested meals was indicated.

The fairly large doses of morphia required to relieve the pain at the onset, and the excessive sweating would almost certainly cause *constipation* and upset the digestion, but it was generally agreed that it is best not to worry the patient with laxatives or enemata until the third or fourth day. At the same time it was important to avoid flatulent distension; a tight belly hampering the diaphragm was an unfair and avoidable handicap to a disabled heart.

In the later stages of the illness from three months onward when the patient would be gradually finding his feet, a new difficulty might present itself, namely, the danger

of his becoming unduly apprehensive about his cardiac condition and drifting into a condition of invalidism. Conversely, the active type of patient, resenting restrictions, might return prematurely to full work and run the risk of overstraining his damaged myocardium with disastrous results.

He agreed with Bain as to the value of oxygen in treatment. Drugs had their place in the alleviation of pain, as mental sedatives, and in the treatment of cardiac failure if and when it appears; but the essential fact to be borne in mind is, that beyond everything, physical rest is the most important factor in enabling the damaged heart to recover.

GILCHRIST (*in absentia*) said that for the relief of pain and for the promotion of mental and physical rest there was no drug to compare with full, and if necessary repeated, doses of morphia. In spite of the relief of pain some patients surviving the initial infarct died in the course of a few days from shock. This aspect of treatment has tended to be neglected, and though there was no specific remedy for this peripheral vascular failure it is possible that more might be done to safeguard the patient. On the other hand, a very large number of patients did very well, after the pain has been relieved, with no active drug treatment. Complete rest in bed might do much more than it was sometimes given credit for, particularly if the rest in bed were complete in every detail.

In the severer cases of shock there was, for instance, a natural hesitation to employ intravenous saline solutions and transfusions of whole blood, although these were commonly given in shock from other causes. In the early stages a plentiful supply of hot water-bottles or preferably a " shock cage ", fitted up with more than the usual electric bulbs and continued for 24 or 48 hours, should be provided. Clinical studies in other related forms of peripheral vascular failure indicated that benefit was likely to be obtained from the use of the active principle of the suprarenal cortex. It had been used after extensive burning injuries and in virtue of its power to regulate water-balance and cellular permeability, a potent extract of suprarenal cortex was worthy of a more extended trial in the severer cases of cardiac infarction. The value of intravenous therapy was doubtful, but concentrated blood serum might be preferable to massive saline infusions or whole blood transfusions.

The development of an abnormal rhythm such as a ventricular tachycardia, with the subsequent development of ventricular fibrillation, was probably more common than supposed, particularly as the patient himself might be unaware of any change in heart rhythm. Quinidine might be used as a preventative measure when the indications were those of an extensive infarct: 0·2 g. at eight-hour intervals was harmless and might be of real benefit. The continuous drip method for the intravenous administration of quinidine as proposed and used by Hepburn and Rykert, was valuable in the treatment of paroxysmal tachycardia. By vigorous shaking, 50 to 60 grains of quinidine sulphate could be dissolved in 500 c.c. of 5 per cent glucose solution; after filtering and warming, the sterile solution should be run at a rate of 1 to 2 c.c. per minute until normal rhythm returns or until cinchonism is induced.

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After luncheon Dr. H. W. Garrod showed the Society round the College, and in particular the Library where there were interesting books and records of Harvey.

Dinner was served in Merton Hall, through the kindness of the Warden, Sir John Miles. Fraser proposed the health of the Society and recalled the early history of the Cardiac Club, founded after the last war.

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